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Experimental Researches
CONCERNING THE
PHILOSOPHY
OF
PERMANENT COLOURS.
VOL. I.

A

permanence des couleurs

CONTRACT

PHILOSOPHY

OF

PERMANENT COLOURS

Experimental

AND THE

Best Means of Producing them, by

Callisto Printing, &c.



BY EDWARD T. GOSSETT

FELLOW OF THE SOCIETY OF ARTS

On the permanence of colours, and on the best means of producing them, by Callisto Printing, &c. The author, Edward T. Gossett, is a Fellow of the Society of Arts, and has published several works on the subject of printing and the arts. This work is a practical treatise on the permanence of colours, and is intended for the use of printers and artists.

VOL. I

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Experimental Researches
CONCERNING THE
PHILOSOPHY
OF
PERMANENT COLOURS;
AND THE
Best Means of producing them, by DYING,
CALLICO PRINTING, &c.

By EDWARD BANCROFT, M.D.
FELLOW OF THE ROYAL SOCIETY, &c.

“ Cet art (de la teinture) est un des plus utiles et des plus merveilleux
“ qu'on connoisse; & si quelque un peut inspirer un noble orgueil à
“ l'homme, c'est celui là: non seulement il a procuré le moyen de
“ suivre et d'imiter la nature dans la richesse & l'éclat des couleurs;
“ mais il paroît l'avoir surpassé en donnant plus d'éclat, plus de fixité
“ & plus de solidité aux couleurs fugaces & passagères dont elle a revêtu
“ tous les corps qui composent ce globe.”

CHAPTAL, *Elémens de Chimie*, tom. iii. p. 185.

VOL. I.

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(SUCCESSORS TO MR. CADELL,) IN THE STRAND.

M DCC XCIV.

Experimental Results

1

Jos: Banks

P R E F A C E.

A Considerable part of this Volume was printed early in the year 1792; but various interruptions have since concurred in delaying its conclusion. A second Volume is intended to follow, and complete my present plan; the materials of which are nearly all provided, though I cannot expect that it will be published until near the end of the ensuing year.

That and the present volume will contain the results of many thousands of experiments, and of much observation and reflection, during the space of twenty-five years, in which this subject has been my principal occupation; and as it will probably continue to occupy a great part of my time, whilst life and health are prolonged to me, I may be allowed to hope, that future discoveries will hereafter enable me to publish at least one other volume as supplementary to these, which are intended to convey all the knowledge I have hitherto acquired on this subject.

The present volume comprehends what I have to offer concerning the different animal, vegetable,

able, and mineral colours, and colouring matters of that class which I have denominated *substantive*, because they do not depend upon any basis or mordant, either for their permanency or their lustre: and also what I have to communicate respecting the colouring matters of an *animal* nature, belonging to the other class or division, which I have called *adjective* colours, because they are capable of being enlivened and fixed only by being adjected or applied upon a suitable basis: and it also contains such of the *vegetable* adjective colouring matters as are used, or capable of being advantageously used, in producing the various shades of yellow.

The second volume is intended to comprehend all the remaining adjective colours and colouring matters, particularly those very interesting ones which are derived from the tribe of *madders*, the different species of *gallium*, and other roots employed in Asia, as well as in Europe, to produce permanent reds; the different red, purple, and other dying woods now in use, with many which never were used, at least in Europe, except by myself; and also the different vegetable matters which become *black* by being combined with iron; respecting which I shall have many new and important facts to communicate. I shall

shall also in the second volume resume and prosecute, as far as I may be able, some abstruse but interesting inquiries relating to the causes which influence not only the production but the variations and decays of colours, of which indeed the present volume affords many intimations, though my final conclusions on this subject have been delayed for the results of particular experiments, which I have not hitherto been able to prosecute satisfactorily. And indeed, respecting some part of what I have been able to do in this intricate enquiry, I may say with M. Sennebier, "*je ne puis dissimuler que j'ai vu varier mes expériences d'une manière propre à me confondre; quoique je suivisse constamment les mêmes procédés, du moins en apparence, je dois le dire, j'ai vu des résultats opposés.*" (Mem^s. Physico-Chym^s. &c.) And perhaps there is none of those who have been long engaged in chymical pursuits, to whom similar difficulties and disappointments have not occurred.

Nothing but a hope that this work may produce considerable public benefit could have induced me, amidst other numerous avocations, thus to employ the time and attention which have been necessary to produce it. I feel, however, that it will be far, very far from deserving the

character of a perfect work, and, in truth, that chymical science is far from having attained that state which is necessary to perfection on this subject. The objects, and the knowledge required for a complete treatise on dying and callico printing, are indeed so various and extensive, that what Sennebier has said of such a performance will always be true, "*Cet ouvrage seroit immense; il ne consiste pas en faits isolés, qu'il suffit d'examiner séparément; c'est un ensemble prodigieux à créer, soit par la réunion des faits connus et de leurs applications, soit par la recherche des faits nouveaux,*" &c.

In arranging the objects of my present undertaking, I have adopted that plan which would, as I thought, best enable me to convey my ideas intelligibly, with the fewest repetitions, and without separating matters essentially connected to each other. In pursuing it, I have endeavoured to avoid minute descriptions of such manual and mechanical operations of dying and callico printing, as are not connected with the principles of the art; because artists know them already, and, to mere speculative readers, a knowledge of them would be useless.

My Readers will see, that I have adopted the terms of the New Chymical Nomenclature,
and

and also (with a very few exceptions) the principles to which it relates: and I have done this, not because I consider them as forming a perfect system, or imagine that we are yet acquainted with all the minute and abstruse causes of chymical effects, but because I consider the new doctrines as according much better with facts than the old; and as being much better suited to become parts of a perfect system, when successive discoveries shall at length afford the means necessary to its attainment. And though there are some truly respectable chymists, whose minds, strongly prepossessed by ideas and opinions formerly received, have not yet become accessible to the superior evidence which supports the new system; yet their number is continually diminishing, and, in a short space, the generation itself, to which those of us belong, who either were, or continue to be, prejudiced on this subject, will *have passed away*; and, judging by the sentiments of those who are likely to stand foremost among our successors, there can be no difficulty in foreseeing which of these systems must prevail.

LONDON, *August 25th, 1794.*

The Reader is desired to correct the following more material Errors of the Press, viz.

Page 16.	line 30.	for	Barthollet read Bertholet.
38.	24.		calor read calor.
62.	19.		diluted read dilated.
97.	12.		Goquet read Goguet.
97.	24.		arundinem read harundinum.
115.	16.	after	vital add the nitrous, or the fixed.
137.	29.	for	Quatrene read Quatremare.
160.	24.		Hallot read Hellot.
160.	30.		forcé read foncé.
166.	6.		Lord Verulum read Lord Verulam.
171.	4.	of note.	cortinem read cortinam.
171.	9.		after digeret add eos.
180.	6.	for	sulphate of alum read sulphate of alumine.
188.	21.		Luteolu read Luteola.
215.	25.		what read that.
215.	4.	of note.	in o water read into water.
225.	22.		spilled read spiffated.
229.	30.		aubicular read orbicular.
263.	6.	of note.	celatant read éclatant.
299.	11.		than read by.
334.	16 & 24.		acetite read acetite.

EXPLANATIONS

OF

NEW TERMS, used in this Volume.

A.

ACETATES.	Salts formed by the combination of the <i>acetic acid</i> , or radical vinegar, with different bases.
Acetate of copper.	Copper combined with the <i>acetic acid</i> .
Acetate of iron.	Iron combined with the <i>acetic acid</i> .
Acetic acid.	Radical vinegar.
Acetites.	Salts formed by the combination of the <i>acetous acid</i> , or distilled vinegar, with different bases.
Acetite of alumine.	Alumine, or earth of alum, combined with the <i>acetous acid</i> .
Acetite of bismuth.	Bismuth combined with the <i>acetous acid</i> .
Acetite of copper.	Copper combined with the <i>acetous acid</i> .
Acetite of iron.	Iron combined with the <i>acetous acid</i> .
Acetite of lead.	Lead combined with the <i>acetous acid</i> .
Acetite of magnesia.	Magnesia combined with the <i>acetous acid</i> .
Acetous acid.	Distilled vinegar.
Acidulous arseniate of pot-ash.	Macquer's arsenical neutral salt; pot-ash, or vegetable alkali, united to the arsenic acid; in which the pot ash not being sufficient

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- sufficient to neutralize this acid, the latter predominates, and the salt is therefore called acidulous.
- Adjective colours or colouring matters.** Colours or colouring matters, which acquire their lustre and permanency by being adjected or applied upon a suitable basis.
- Ammoniac.** Caustic volatile alkali. Volatile spirit of sal ammoniac.
- Ammoniates.** Combinations of ammoniac with different bases.
- Ammoniate of copper.** Copper combined with ammoniac.
- Arseniates.** Salts formed by the combination of the arsenic acid with different bases.
- Arsenic acid.** The acid which is obtained from arsenic.
- Azote.** Phlogisticated air of Priestley and others; the basis of the nitrous acid; and hence also called nitrogen by Chaptal, &c.

B.

- Barytes.** Earth of ponderous spar.

C.

- Caloric.** Matter or substance of heat. Latent heat.
- Carbonates.** Combinations of the carbonic acid with different bases.
- Carbonate of ammoniac.** Ammoniac united to the carbonic acid. Concrete, or mild volatile alkali.
- Carbonate of lime.** Chalk. Aerated calcareous earth.
- Carbonate of potash.** Mild fixed vegetable alkali. Salt of tartar.
- Carbonate of soda.** Fixed mineral alkali.
- Carbone.** Pure charcoal, or the basis of charcoal.
- Carbonic acid.** The acid obtained from carbone, in the form of an elastic fluid or gaz. Commonly called fixed air.

Citrates.

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Citrates.	Salts formed by the combination of the citric acid, or acid of lemons with different bases.
Citrate of alumine.	Alumine united to citric acid.
Citrate of tin.	Tin dissolved by, or combined with, citric acid.
Citric acid.	Acid of lemons.

F.

Fluates.	Salts formed by the union of the fluoric acid with different bases.
Fluate of tin.	Tin combined with fluoric acid.
Fluoric acid.	Spathose acid.

G.

Gaz or gas.	An elastic or æriform fluid.
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H.

Hydrogenous gaz.	Inflammable air.
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M.

Muriates.	Salts formed by the combination of the muriatic acid with different bases.
Muriate of alumine.	Alumine combined with muriatic acid.
Muriate of ammoniac.	Ammoniac combined with muriatic acid.
Muriate of antimony.	Antimony combined with muriatic acid.
Muriate of barytes.	Barytes combined with muriatic acid.
Muriate of bismuth.	Bismuth combined with muriatic acid.
Muriate of cobalt.	Cobalt combined with muriatic acid.
Muriate of copper.	Copper combined with muriatic acid.
Muriate of iron.	Iron combined with muriatic acid.
Muriate of lead.	Lead combined with muriatic acid. Horned lead.
Muriate of lime.	Lime combined with muriatic acid.
Muriate of magnesia.	Magnesia combined with muriatic acid.

Muriate

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Muriate of mercury.	Mercury combined with muriatic acid.
Muriate of silver.	Silver combined with muriatic acid.
Muriate of soda.	Soda combined with muriatic acid. Common sea salt.
Muriate of tin.	Tin combined with muriatic acid.
Muriate of zinc.	Zinc combined with muriatic acid.
Muriatic acid.	Acid of sea salt. Marine acid.
Murio-nitrates.	Salts formed by the combination of the muriatic and nitric acids with different bases; the muriatic acid being in the greatest proportion.
Murio-nitrate of tin.	Solution of tin, by the muriatic and nitric acids.
Murio-sulphates.	Combinations of the muriatic and sulphuric acids with different bases; the muriatic acid being in the greatest proportion.
Murio-sulphate of bismuth.	Solution of bismuth, by the muriatic and sulphuric acids.
Murio-sulphate of tin.	Solution of tin, by the muriatic and sulphuric acids.
Murio-sulphate of zinc.	Solution of zinc, by the muriatic and sulphuric acids.
Murio-tartrites.	Combinations of the muriatic and tartareous acids with different bases; the muriatic acid being in the greatest proportion.
Murio-tartrite of tin.	Tin dissolved by the muriatic and tartareous acids.

N.

Nitrates.	Salts formed by the combination of the nitric acid with different bases.
Nitrate of alumine.	Alumine combined with nitric acid.
Nitrate of antimony.	Antimony combined with nitric acid.
Nitrate of barytes.	Barytes combined with nitric acid.
Nitrate of bismuth.	Bismuth combined with nitric acid.
Nitrate of cobalt.	Cobalt combined with nitric acid.
Nitrate of copper.	Copper combined with nitric acid.
Nitrate of iron.	Iron combined with nitric acid.

Nitrate

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Nitrate of lead. Lead combined with nitric acid.
 Nitrate of lime. Lime combined with nitric acid.
 Nitrate of magnesia. Magnesia combined with nitric acid.
 Nitrate of manganese. Manganese combined with nitric acid.

Nitrate of mercury. Mercury combined with nitric acid.
 Nitrate of nickle. Nickle combined with nitric acid.
 Nitrate of pot-ash. Pot-ash combined with nitric acid.
 Nitre or saltpetre.

Nitrate of silver. Silver combined with nitric acid.
 Nitrate of tin. Tin combined with nitric acid.
 Nitrate of zinc. Zinc combined with nitric acid.
 Nitric acid. Dephlogisticated nitrous acid. Colourless aqua-fortis or acid of nitre, in which the basis or azotic part is fully saturated with oxygene.

Nitrites. Combinations of the *nitrous* acid with different bases.

Nitrous acid. Phlogisticated nitrous acid. Red or smoking spirit of nitre, in which the azotic basis is not fully saturated with oxygene.

Nitro-muriates. Salts, formed by the combination of the nitric and muriatic acids with different bases, in which the nitric acid is in the greatest proportion.

Nitro-muriate of Antimony combined with nitric and muriatic acids.

Nitro-muriate of Bismuth combined with nitric and muriatic acids.

Nitro-muriate of Gold combined with nitric and muriatic acids.

Nitro-muriate of Platina combined with nitric and muriatic acids.

Nitro-muriate of Tin combined with nitric and muriatic acids.

Nitro-muriatic acid. A mixture of the nitric and muriatic acids; formerly called aqua regia.

O.
 Oxide or oxyd. The combination of a metal with oxygene in a solid form, formerly called Calx.

Oxygene.

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Oxygene.	The basis of pure or vital air. The aërial acidifying principle.
Oxygenated muriatic acid.	Muriatic acid, with an addition of oxygene; formerly called dephlogisticated marine acid.
Oxygenated muriatic acid gaz.	The oxygenated muriatic acid combined with caloric, by which it is raised into the form of an elastic fluid.
P.	
Phosphates.	Salts formed by the combination of the phosphoric acid with different bases.
Phosphate of tin.	Tin combined with phosphoric acid.
Pot-ash.	Caustic vegetable alkali.
Prussian or Prussic acid.	The acid of Prussian blue.
Prussiates.	Combinations of the Prussic acid with different bases.
Prussiate of ammoniac.	Ammoniac combined with Prussic acid, or colouring principle of Prussian blue.
Prussiate of lime.	Lime combined with Prussic acid.
Prussiate of pot-ash.	Pot-ash combined with Prussic acid.
Prussiate of soda.	Soda combined with Prussic acid.
Pyroligneous acid.	The empyreumatic acid, obtained by distillation from wood, &c.
Pyrolignites.	Combinations of the pyroligneous acid with different bases.
Pyrolignite of iron.	Iron combined with pyroligneous acid.
Soda.	Caustic fossil alkali.
Substantive colouring matter.	Colouring matter which requires no basis or mordant to give it lustre or permanency.
Sulphates.	Salts formed by the combination of the sulphuric acid with different bases.
Sulphate of alumine.	Alumine combined with sulphuric acid. Common alum.
Sulphate of barytes.	Barytes combined with sulphuric acid.
Sulphate of bismuth.	Bismuth combined with sulphuric acid.
	Sulphate

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Sulphate of copper.	Copper combined with sulphuric acid. Blue vitriol.
Sulphate of indigo.	Indigo combined with sulphuric acid.
Sulphate of iron.	Iron combined with sulphuric acid. Green vitriol, or copperas.
Sulphate of lime.	Lime combined with sulphuric acid. Selenite.
Sulphate of magnesia.	Magnesia combined with sulphuric acid. Epsom salt.
Sulphate of manganese.	Manganese combined with sulphuric acid.
Sulphate of pot-ash.	Pot-ash combined with sulphuric acid. Vitriolated tartar.
Sulphate of tin.	Tin combined with sulphuric acid.
Sulphate of zinc.	Zinc combined with sulphuric acid.
Sulphure or sulphuret of antimony.	Combination of sulphur with antimony; formerly called crude antimony.
Sulphure of arsenic.	Combination of sulphur with arsenic.
Sulphure of pot-ash.	Sulphur united to pot-ash; or liver of sulphur.

T.

Tartaro-nitrates.	Combinations of the tartareous and nitric acids with different bases; the tartareous acid being in the greater proportion.
Tartaro-nitrate of tin.	Tin combined with the tartareous and nitric acids.
Tartaro-sulphates.	Combinations of the tartareous and sulphuric acids with different bases; the tartareous acid being in the greater proportion.
Tartaro-sulphate of tin.	Tin combined with the tartareous and sulphuric acids.
Tartrites.	Combinations of the tartareous acid with different bases.
Tartrite of alumine.	Alumine combined with tartareous acid.
Tartrite of tin.	Tin combined with tartareous acid.

EXPLANATION OF THE TERMS

1. The first term is the name of the person who has written the book. It is the name of the author.

2. The second term is the name of the book. It is the title of the work.

3. The third term is the name of the place where the book was written. It is the place of origin.

4. The fourth term is the name of the year when the book was written. It is the date of publication.

5. The fifth term is the name of the edition of the book. It is the version of the work.

6. The sixth term is the name of the publisher of the book. It is the person or company that has printed the book.

7. The seventh term is the name of the printer of the book. It is the person or company that has printed the book.

8. The eighth term is the name of the bookseller of the book. It is the person or company that has sold the book.

9. The ninth term is the name of the library of the book. It is the place where the book is kept.

10. The tenth term is the name of the collection of the book. It is the group of books to which the book belongs.

11. The eleventh term is the name of the subject of the book. It is the topic of the work.

12. The twelfth term is the name of the genre of the book. It is the type of work.

13. The thirteenth term is the name of the style of the book. It is the way in which the work is written.

14. The fourteenth term is the name of the language of the book. It is the language in which the work is written.

15. The fifteenth term is the name of the country of the book. It is the country in which the work was written.

16. The sixteenth term is the name of the continent of the book. It is the continent in which the work was written.

17. The seventeenth term is the name of the world of the book. It is the world in which the work was written.

18. The eighteenth term is the name of the universe of the book. It is the universe in which the work was written.

19. The nineteenth term is the name of the multiverse of the book. It is the multiverse in which the work was written.

20. The twentieth term is the name of the omniverse of the book. It is the omniverse in which the work was written.

C O N T E N T S.

INTRODUCTION, respecting the origin and progress of
dying; and the means, authors, &c. by which it
has been improved.

C H A P. I.

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INTRODUCTION.

THE Great Author of Nature having allotted and employed colours, as means of distinguishing and adorning the various productions of his power, wisdom, and goodness, has also endowed some animals, and particularly man, not only with perceptions of the differences of colours, but also of the beauty arising from them and their various combinations: and it is in consequence of these perceptions that mankind, even in the rudest states of human existence, have been found to manifest great admiration and desire for ornaments depending on gaudy and varied colours; which, at first, naked savages generally applied to their skins, and afterwards to their garments, when they had approached so far towards civilization as to manufacture and wear cloathing. To these motives, and to the rude trials induced by them, even in remote ages, the arts of dying and callico printing undoubtedly owe their origin.

It will appear in the following chapters, that colouring matters are of two very distinct classes; one which requires no basis or mordant to fix it upon other objects, and which I have therefore denominated *substantive* colouring matter; and the other, whose durability depends chiefly, if not wholly, upon the interposition of some basis,
and

and which, for that reason, I have called *adjective* colouring matter; and as, among colouring matters, those of the adjective class would naturally present themselves in the greatest abundance, and be applied without any means to render them permanent, (because it would require numerous trials, and a concurrence of many fortunate accidents to discover the use of any basis or mordant,) we may reasonably conclude, that most of the stains or dyes first applied to different substances would in all countries have been fugitive. Such, according to Pliny, were those of the Gauls*, and such have been the greatest part of those employed by the uncivilized inhabitants of all the newly-discovered countries: and we may therefore consider the discovery of the effects of bases or mordants, and particularly of alum, in fixing adjective colouring matters, as a most important event in the history of dying. When or where this discovery was first made cannot be ascertained; there is, however, good reason to believe, that alum, and probably iron, (which are the principal bases of modern callico printing,) were employed by the Egyptians in producing those effects which are described by Pliny, L. xxxv. § 42; because

* "*Transalpina Gallia herbis Tyrium atque conchilium tingit, omnesque alios colores—Sed culpa non ablui usu.*" Lib. xxii. § 3. This however was not always the case in other countries: Herodotus mentions a people living on the borders of the Caspian sea, who by bruising the leaves of a particular tree, and mixing them with water, obtained a colour by which they afterwards painted or stained their garments with the figures of animals, &c. which figures, he adds, water could not efface; on the contrary, they remained until the cloth was worn out, as if they had been woven therein. Book C. l. 10. c. c. iii.

they

they resemble others which callico printers now obtain by these means, and which at this time they cannot obtain by any other, even with all the knowledge since acquired: and, in the seventh chapter of this volume, facts and reasons are adduced, to prove that the Egyptians borrowed this art from Hindostan, where it appears to have subsisted for more than two thousand years, probably with very little if any variation or improvement during that long space of time: and if we may judge of the means formerly employed in Hindostan for dying or staining calicoes by those which were found to be in use for that purpose, when the nations of Europe first went thither by the Cape of Good Hope, we may safely conclude, that solutions of alum and of iron must have been the mordants employed in fixing their adjective colours. Hindostan appears also to have been the country where that wonderful substantive colouring matter called indico, or indigo, was first produced. The uncivilized inhabitants of other countries indeed have found out ways of obtaining substantive blue colouring matters, very nearly resembling that of indigo, from different plants, particularly from the *isatis tinctoria* Linn., or woad, and from the *genipa Americana* Linn., but they obtained these matters in a liquid form only. The people of India however went farther; they precipitated and collected in a dry solid form the colouring matter of indigo, and, what must have been a matter of much greater difficulty, they afterwards discovered the means of dissolving it, and rendering it capable of being permanently fixed upon the substances intended to be stained or dyed with it; an effect which the Greeks and

Romans do not appear to have ever produced, though they knew how to powder and apply indigo as a paint.

From the fifth volume of that extensive Work intituled, "*Memoires concernants l'Histoire, les Sciences, les Arts, les Moeurs, &c. des Chinois,*" it appears that wool was never worn in China but as a substitute for fur, and that cotton and silk, being the only substances ever dyed by the inhabitants, received all their colours from vegetable tingent matters; that these colours were principally red, blue, violet, and what is called a woad colour; and that under the three first dynasties, the business of dying was chiefly practised by the female part of each family, for its own particular use: and it probably continued to be practised without any thing like principle or science until near the end of the seventh century, when the Chinese, discarding their own, borrowed the art and means of dying which were then in use among the Indians and Persians: and it is said, that alum and copperas, which the Chinese did not use before, were among the means so borrowed; a fact which renders it probable that there was little, if any thing, in the Chinese art of dying, of which the loss need now be regretted.

It appears however that, long before this time, a knowledge of the uses of alum and of iron in dying, had spread from Hindostan and Persia westward to Egypt, and thence to Greece and Rome. Bergmann indeed, (*de Confect. Alum,*) and after him Beckmann, (*in the Göttingen Memoirs,*) have represented the alum of the
antients

antients as different from the crystallized salt so called by the moderns; and have supposed, that the varieties of alum mentioned by Dioscorides were stalactites, containing but little alum, and consisting chiefly of calcareous earth, which, in certain proportions, will hereafter appear to be a very useful addition for most of the colours depending on an aluminous basis. Nature however does produce some, though but little crystallized alum, particularly in Egypt and some parts of Asia; and it probably was in this state that its good effects in dying had been first observed, before mankind were led to the means and operations since employed for separating and collecting it from the various aluminous ores. Bergmann says, that "the factitious salt which is now called alum, was first discovered in the Eastern countries;" and that "among the most early works established for the preparation of alum, we may justly number that of *Roccho*, a city in Syria, now called *Edeffa*: hence the appellation of *roch alum*." See vol. I. p. 339. of the English Translation of his *Essays*. He adds, that "Bartholomew Perdux or Pernix, a merchant of Genoa, who had been at *Roccho*, discovered the matrix of alum in the island of *Ischia*, about the year 1459, and established a manufactory there; at the same time John de Castro, who had visited the manufactories at Constantinople, discovered a matrix at *Tolfa*, by means of the *ilex aquifolium*, which he had also observed to grow in the adjacent mountains of Turkey, and his opinion was confirmed by the taste of the stones. The attempts made by the Genoese at *Viterbium* and at *Vola-*

“ terre succeeded extremely well; the preparation of it in Italy soon increased wonderfully fast, &c. The first manufactory (of alum) in England was established in the reign of Elizabeth at Gisborough, by one Thomas Chaloner.”

It is now very difficult to ascertain the particular adjective colouring matters, in the fixing of which, alum was used among the antients, by reason of the imperfect descriptions and means employed by them to characterise and distinguish the different objects of natural history. Some species of madder however (and perhaps of galium) were undoubtedly used by the people of Hindostan, Persia, and Egypt, as well as by the Greeks and Romans; and the kermes insect was also employed by the latter for dying reds. I do not find any account of the particular means by which yellows were dyed among the antients; but there must have been many vegetables in all countries capable of producing that colour with alum.

Of substantive colours used by the Greeks and Romans, the most considerable was the famous Tyrian purple, supposed to have been first discovered by the Phenicians, and of which a very full account is given in the fourth chapter of this Work.

But whatever knowledge the Greeks and Romans had derived from others, or acquired by their own observations, appears to have been in a great degree lost about the fifth century; when, as M. Berthollet has observed, scarce any

any traces of science, industry, or humanity were left in what was then called the Western Empire; a little however did remain, and it was afterwards preserved in Italy, where the Venetians contrived to import many oriental productions and manufactures, which, by affording new means, as well as new objects of imitation, contributed greatly to revive the arts.

According to M. Berthollet, the first collection of processes used in dying was published at Venice in 1429, under the name of *Mariegola dell'Arte de Tintori*, of which another edition much improved appeared in 1510; and from this an individual named Giovanne Ventura Rosetti, who travelled into different parts of Italy and the neighbouring countries, to learn the methods and means employed in dying, composed, and in 1548 published a work under the title of *Plictho dell'Arte de i Tintori*, &c. which has been supposed to have contributed more than any other to the improvements afterwards made in that art. In this work however there is no mention of either indigo or cochineal, which M. Berthollet therefore concludes were not at that time employed by the Italian dyers. This appears to have been the work which, at a meeting of the Royal Society on the 30th of April 1662, Mr. Haak was desired to translate into the English language (see Dr. Birch's History). That learned body had, upon its first institution, bestowed some attention to the subject of dying, and on the same day Sir William Petty, one of its earliest and most active members, in consequence of a previous

request from the Society, brought in "An Apparatus to the History of the Common Practices of Dying," which was afterwards printed in Dr. Spratt's History of the Royal Society, and seems to have been the first account published in the English language of the means and operations used by dyers. Nearly two years afterwards, viz. March 30, 1664, Mr. Boyle presented to the Royal Society his "Experiments and Considerations touching Colours;" and, on the 10th of August following, it was ordered by the Society "that the way of *fixing colours* should be recommended to Mr. Howard, Mr. Boyle, and Dr. Merrit." These, and especially the two first, were among the most distinguished members of the Society; but it does not appear that they were able to do any thing deserving of notice, in consequence of this recommendation. However, at a meeting of the Society on the 11th November 1669, that very ingenious and useful member, "Mr. Hooke, produced a piece " of callico stained after the way contrived by " himself, which he was desired to prosecute in " other colours besides those that appeared in " this piece" (Birch's Hist. of the Royal Society, vol. ii. p. 401.): And accordingly, on the 9th of the following month, "Mr. Hooke " produced another specimen of staining with " yellow, red, green, blue, and purple colours, " which he said would endure washing with " warm water and soap." But from this time it does not appear that any thing considerable was done, for nearly the space of a century, by men of science in this kingdom, towards improving the arts of dying and callico printing; they being probably discouraged by the difficulties

which,

which, from the very imperfect state of chymical science, must have occurred in every attempt to improve upon what the dyers were able to perform without any principle or theory.

In France however the minister Colbert, anxious to extend the commerce and manufactures of that country, turned his attention particularly to the art of dying, with a view to amend as well as to obviate frauds in the practice; and for these purposes, an "Instruction générale pour la Teinture des Laines & Manufactures de Laine de toutes Nuances, et pour la Culture des Drogues ou Ingrédients qu'on emploie," was prepared under his immediate direction, and published in 1672. This however was not intended merely to inform, but as a legislative act to control the dyers in their operations. It divided them into two classes; the one, dyers "*en grand*," were confined to the colours deemed lasting, while the dyers "*en petit teint*" were allowed only to give those which were considered as fugitive: and the drugs to be employed in each branch were also particularly specified; and the dyers in each prohibited from using or having in their possession any of the drugs allotted to the other. Restraints of this kind, though intended to prevent frauds, must have operated as checks upon future improvements, if the government had not encouraged useful discoveries in this art, first by offering particular rewards, and afterwards by appointing those eminent chymists, Dufay, Hellot, Macquer, and Berthollet, in succession, to superintend and improve the arts connected with chymistry, and more especially that of dying.

By Dufay's assistance M. Colbert's "Instruction" was amended, or rather superseded by a new one, published under the administration of M. d'Orry in 1737. He (Dufay) appears to have been the first who entertained just conceptions of one of the causes of the adhesion of colouring matters to stuffs when dyed; I mean that which depends on an affinity or attraction subsisting between such matters and the fibres or substances of the dyed stuffs. He clearly perceived that, without this, cloth while in the dying vessel could only acquire a degree of colour equal to that of the dying liquor, by an equal participation of the colouring matter dissolved therein; whereas in fact the cloth is often seen to exhaust, by attracting to itself, all the tingent particles of the dying liquor, so as to leave it as colourless as water. He also noticed the difference in the degree of attraction, which different substances, as wool and cotton, exert upon the same colouring matters; and which he found so great, that a skain of each having been in an equal degree subjected to the means and operations commonly employed for dying scarlet, the woollen yarn was found to be fully and permanently dyed of that colour, while the cotton retained all its former whiteness*. He appears however to have had no conception of the other and more important cause of the permanency of adjective colours, I mean that which arises from the interposition of a suitable basis possessing a particular attraction both for the colouring matter and for the dyed substance, and thereby

* Observations Physiques sur le Mélange de quelques Couleurs dans la Teinture, Mémoires de l'Académie R^o. &c. 1737.

acting as a *bond of union between them*: nor did his successor Hellot ever approach nearer to the truth on this subject. He, (Hellot,) indeed, published an excellent practical treatise on the art of dying wool and woollen cloths, in which the several processes were accurately described: but in reasoning upon the facts stated therein, he adopted, and suffered himself to be grossly misled by, a frivolous hypothesis, devoid of the least foundation in truth. He fancied that he could discover, in every dying process, some means by which sulphate of pot-ash (then called vitriolated tartar) might be formed; and this neutral salt not being readily soluble by cold water, nor by air or light, he conceived the whole art of dying to consist in first dilating the pores of the substance to be dyed, so as to procure a copious admission of colouring matter, divided by a suitable preparation into atoms, and then wedging or fastening these atoms within the pores of the dyed substance, by the small particles or crystals of this difficultly soluble neutral salt. Upon this *mechanical* hypothesis, he supposed that alum became useful in dying, not by the pure clay or alumine which it contains, and which alone contributes to fix any colouring matter, but by furnishing (and only by furnishing) sulphuric or vitriolic acid, to assist in forming the sulphate of pot-ash, which was to perform this important function of wedging or fastening the colouring atoms; though if he had brought this visionary hypothesis to the test of experiment, as might have been easily done, he would have found not only that no sulphate of pot-ash existed in many cases where he supposed it to produce such important effects, but also that,
even

even if intentionally formed and employed for this purpose, it possessed no power whatever of fixing any colouring matter yet known. But though nothing could be more groundless than this theory, the learned in all countries appear to have been satisfied with it for a considerable length of time, it being always less troublesome to believe than to make experiments. The late celebrated Macquer in a Memoir, printed among those of the Royal Academy of Sciences for 1749, mentioning Hellot and his hypothesis, says, "ce
 " savant chymiste est le premier qui ait porté
 " le flambeau de la physique dans l'art obscur
 " de la teinture, & qui ait rassemblé et mis en
 " ordre, suivant les principes d'une théorie ingénieuse, les phénomènes et les opérations
 " bizarres de cet art : il a mis les chymistes à
 " portée de voir clair dans ce cahos ténébreux." And afterwards, in the preface to an excellent *Practical Treatise on Dying Silk*, published in 1763, he makes this observation, "ce seroit ici le lieu
 " d'expliquer la manière dont les mordants agissent dans la teinture, et de développer la cause
 " du bon et du faux teint ; mais ces objets ont été
 " traités avec tant de sagacité par M. Hellot, que
 " je crois devoir y renvoyer le lecteur ;" and even so lately as the year 1766, in an eulogium pronounced upon Hellot in the Royal Academy of Sciences after his decease, and published with the *mémoires* for that year ; the secretary, after explaining Hellot's hypothesis, says, "à l'aide de
 " cette théorie si lumineuse, on ne sera plus
 " trompé dans la pratique de cet art, que lors
 " qu'on voudra bien l'être."

Mr. Henry of Manchester has truly observed, that " Mr. Keir, the ingenious translator of
 " Macquer's

“ Macquer’s Chymical Dictionary, appears to
“ have been the first who suspected that (in
“ dying) the earth of alum was precipitated, and
“ in this form attached to the material prepared
“ or dyed;” and this idea, having been published, was adopted by Mr. Macquer, and farther extended in the last edition of his “ Dictionnaire de Chymie,” at the article “ Teinture,” where he seems to have formed just conceptions of the nature and uses of alum, and of different metallic solutions, as mordants, in dying. This edition was published in the year 1778, and Mr. Macquer soon after announced a design of writing a general treatise on the art of dying, which his death however frustrated. Some time after M. Macquer’s decease, the ingenious Mr. Henry of Manchester favoured the public with a very interesting paper, (in the 3d volume of the Memoirs of the Manchester Society,) “ On the
“ Nature of Wool, Silk, and Cotton, as Objects
“ of the Art of Dying; on the various Preparations and Mordants requisite for these different Substances; and on the Nature and
“ Properties of Colouring Matter, &c.” a paper replete with useful information and ingenious ideas, (particularly respecting the causes of the durability of what is called the Turkey red,) and which deservedly reflects great credit on the author’s talents and acquirements. And in the year 1791, that most excellent chymist M. Berthollet, who had been appointed by the government of France to succeed M. Macquer in superintending the arts connected with chymistry, and particularly dying, published a work of great merit, under the title of “ Elémens de l’Art de la Teinture,” in two volumes, which has since been translated into English by Dr. Hamilton.

Before

Before the publication of Mr. Berthollet's work, I had collected most of the materials for this undertaking; and, though he has anticipated many things which I was prepared to mention, (some of which I shall notwithstanding mention in my own way,) this production afforded me great pleasure as well as profit; because the author's superior chymical knowledge has enabled him to take just views of many intricate parts of his subject, and to reason with solidity, as well as sagacity, upon the operations of dying in general, probably without having had leisure to do much *experimentally* towards their improvement. He has moreover enabled me to abridge my own work, by referring to his, for more ample information upon several topics, particularly those of fuel, the different acids, alum, the sulphates of iron, copper, and zinc, verdigrise, acetite of lead, the different alkalies, soap, sulphur, arsenic and water, of all which he has treated so ably and fully as to leave but very little for me to add respecting any of them.

But though I have been preceded by authors of such distinguished ability as Mr. Henry and M. Berthollet, the new facts and observations which I have to offer my readers will shew that I did not find the subject exhausted: And indeed it is so far inexhaustible that it probably will afford ample employment for the greatest talents and industry during many generations.

In justice to that very respectable chymist Mr. Chaptal, I ought to mention that his excellent work intituled, "*Elemens de Chimie*," and published

published in the year 1790, (in three volumes,) contains many ingenious facts and observations relating to the causes of the production and changes of colours, as well as to several other subjects connected with dying. Some other works deserving of notice have also within a few years been published on this subject, particularly that of Scheffer with notes by the celebrated Bergmann; another by Pœrner, which has been translated into French from the German, and published with notes by Desmarests and Berthollet; and a third by Dambourney; but neither of these has done much towards improving the theory of dying. That of Pœrner contains an account of many experiments made by the author with different dying drugs; but unfortunately his reasonings upon them, and upon every part of the subject, are highly defective. Dambourney (a respectable merchant) was possessed of no chymical science, and he has done little more than give an account of the trials which he made with a considerable number of vegetable matters; few of which are likely to be ever much, if in any degree, employed by dyers.

Of the introduction of callico printing into Europe, and its progress, my readers will find an account in the seventh chapter of this volume.

Eminent Writers have derived the arts of dying and callico printing from a considerable degree of perfection, which they suppose chymistry to have somewhere attained in remote ages, though afterwards lost; and they imagine that particular processes of the art were preserved after

after the principles on which it was founded had been forgotten*: I am not able however to perceive any sufficient ground for these opinions. In fact, there is no good reason to believe, that chymistry ever had made any such progress among the antients, or that they ever were so much engaged in the pursuit of knowledge by *experiment*, as would have been necessary for the acquisition of but a moderate portion of chymical science †. Even the operations of callico printing, as practised by the people of India, and which above all others have been considered as the result of an improved state of chymistry, are in many respects highly inconvenient, and incumbered with useless parts which a little chymical knowledge would have taught them to reject, as indeed they were rejected by the people of Europe very soon after callico printing began to be practised here, though it began and was continued for some time with little or no aid from chymical science. And considering how far many of the operations of dying and callico printing have been carried towards perfection, unassisted by principles, we may say of this art, or until very lately might have said what Lord Bacon says of music, that “the practice has been well pursued and in good variety, but the theory weakly; especially as to assigning the causes of the practice.” Bacon’s Works, by Mallet, vol. III. p. 29.

* See Mr. Henry’s paper in the third volume of the Memoirs of the Manchester Society. Also Hist. & Memoires de l’Acad. R. des Sciences, &c. 1750, and 1766.

† Pliny observes, that dying had never been considered as a liberal art; and he alleges this, as an excuse for not giving a *rationale* of it. Lib. xxii. § 3. But it was a mere excuse, because no degree of science then in the world could have enabled him to do so.

But

But notwithstanding the observations of many individuals occupied with the means and operations of dying, through a long succession of ages in different countries, joined to very important *accidental* discoveries occurring from time to time, have produced great improvements in this art, with but little help from theory, we are not to infer that a knowledge of its true principles, and of the causes which operate in producing its various effects, will not prove useful in the highest degree: for “ though (as Mr. Henry has well observed) long experience “ may establish a number of facts, yet, if the “ rationale of the manner by which they are “ produced be not understood, misapplications “ are liable to be made; similar practices are “ pursued where the cases differ essentially; and “ improvements are attempted at hazard, and “ often on false principles.” And in confirmation of these truths, perhaps I cannot better conclude this Introduction, than by adding the following quotation from the History and Memoirs of the Royal Academy of Sciences at Paris, for the year 1761, viz.

“ *La description des arts, faite avec une*
“ *exactitude éclairée, deponillée de toutes les*
“ *pratiques inutiles que l'ignorancé tousjours*
“ *mysterieuse y accumule sans cesse, & reduire*
“ *aux principes constans de la saine theorie, est*
“ *peutetre le moyen le plus propre a biter leur*
“ *perfection, et a rendre plus abondantes ces*
“ *sources de biens & de commodités, que*
“ *l'etre supreme a voulu que les hommes*
“ *dussent a leur travail, et a leur industrie.*”

Expe-

INTRODUCTION

The Department of the Interior of the United States has the honor to acknowledge the receipt of the report of the Commissioner of the General Land Office, dated at Washington, D. C., the 1st day of January, 1880, in relation to the progress of the work of the Department during the year 1879. The report is a valuable contribution to the knowledge of the Department, and it is a pleasure to publish it in this form, so that it may be accessible to all interested parties. The report is divided into two parts, the first of which contains a general statement of the work of the Department, and the second part contains a detailed statement of the work of the various bureaus and offices. The report is a valuable contribution to the knowledge of the Department, and it is a pleasure to publish it in this form, so that it may be accessible to all interested parties.

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Experimental Researches

CONCERNING THE PHILOSOPHY OF

PERMANENT COLOURS,

AND THE

Best Means of producing them, by DYEING,
CALLICO PRINTING, &c.

CHAP. I.

Of the permanent Colours of Natural Bodies.

“ Ceux qui exigent qu'on leur donne la raison
“ d'un *effet general*, ne connoissent, ni l'*etendue*
“ de la nature, ni les limites de l'esprit humain.”

M. DE BUFFON.

THE subject of this chapter was covered with almost total darkness, until the immortal Newton threw light upon it, by *dissecting*, if I may so express myself, the *matter of light* itself. By his Experiments we have been taught, that “ the light of the sun consists of rays differently *refrangible* ;” and that, when separated by the prism, in consequence of their different degrees of refrangibility, they afford all the various shades of colour, running gradually into each other, according to their particular degrees of refrangibility; the violet
B being

being most refracted; the indigo next; then the blue, green, yellow, orange, and red, which, of all others, is the least refracted; that the same rays also differ in degrees of reflexivity, according to their degrees of refrangibility.

That the proper colour of homogeneous light, depending on its particular degrees of refrangibility, cannot be changed by reflections or refractions; and “if the sun’s light consisted of but one sort of rays, there would be but one colour in the whole world,” nor the possibility of producing any new colour by reflections and refractions; and therefore, “that the variety of colours depends upon the composition of light.”

That “colours, *in an object*, are nothing but a disposition to reflect this or that sort of rays, more copiously than the rest; *in the rays*, they are nothing but their dispositions to propagate this or that motion into the sensorium; and *in the sensorium*, they are sensations of those motions, under the *forms of colours*.”

That “colours may be produced by composition, which shall be like to the colours of homogeneous light as to the *appearance of colour*, but not as to the immutability of colour and constitution of light; and those colours, by how much they are more compounded, by so much are they less full and intense; and by too much composition they may be diluted and weakened, till they cease, and the mixture becomes grey. There may be also colours produced by composition, which are not fully like any of the colours of homogeneous light.” “For a mixture
of

of homogeneous red and yellow compounds an orange, like, in appearance of colour, to that orange which, in the series of unmixed prismatic colours, lies between them; but the light of one orange is homogeneous as to the refrangibility, and that of the other is heterogeneous; and the colour of the one, if viewed through a prism, remains unchanged; that of the other is changed, and resolved into its component colours, red and yellow. And after the same manner other neighbouring homogeneous colours may compound new colours, &c." And if to a colour so compounded other colours be added in sufficient quantities, they will gradually overcome the first, and produce "whiteness, or some other colour." "So if to the colour of any homogeneous light, the sun's white light, composed of all sorts of rays, be added, that colour will not vanish or change its species, but be diluted; and by adding more and more white, it will be diluted more and more perpetually." "Lastly, if red and violet be mingled, there will be generated, according to their various proportions, various purples, such as are not like, in appearance, to the colour of any homogeneous light; and of these purples, mixed with yellow and blue, may be made other new colours." "That whiteness, and all grey colours between white and black, may be compounded of colours, and the whiteness of the sun's light, is compounded of all the primary colours mixed in due proportion." To illustrate this, he produced *whiteness*, first by a mixture of the prismatic colours, and then by mixtures of differently coloured substances, in due proportions.

Each particular colour being therefore a property of that particular sort of ray which produces the perception thereof, Sir Isaac Newton concludes, that the permanent colours of natural bodies arise from hence, that some of them "reflect some sorts of rays, others other sorts, more copiously than the rest." "Minium reflects the least refrangible, or red making rays most copiously, and thence appears red. Violets reflect the most refrangible most copiously, and thence have their colour, and so of other bodies;" and "whilst bodies become coloured, by reflecting or transmitting this or that sort of rays more copiously than the rest, it is to be conceived that they stop and stifle in themselves the rays which they do not reflect."

Sir Isaac Newton's demonstrations and illustrations of this doctrine may be seen at large in the *first* Book of his Optics, to which I beg leave to refer, without presuming to offer the smallest objection thereto. The celebrated Euler has, indeed, conceived light to be propagated like sound, by a vibrating motion, and that the different degrees of velocity, or frequency with which these motions or vibrations successively reach the organs of vision, occasion the sensations or perceptions of the different colours, as those of air occasion the differences of sound, and that colours are to the sight, what sounds are to the organs of hearing. But this analogy, though it may serve to illustrate, will not prove the truth of his opinion; and as he does not offer any other satisfactory proof of it, or any means to overcome the difficulties with which it is attended, I shall thus far adhere to Sir Isaac Newton's

ton's doctrine. His *second* Book, however, appears to contain matter which is liable to considerable objection. He begins it with "Observations concerning the reflections, refractions, and colours of thin transparent bodies;" and mentions what had been observed by others, "that transparent substances, as glass, water, air, &c. when made very thin by being blown into bubbles, or otherwise formed into plates, do exhibit various colours, according to their various thinness; although at a greater thickness they appear very clear and colourless." And though he considers these colours as "*of a more difficult consideration*," yet as "they may conduce to farther discoveries for completing the theory of light, *especially as to the constitution of the parts of natural bodies, on which their colours or transparency depend*," he delivers his own observations on this subject: Of these, the principal was made, by taking "two object glasses, the one a planoconvex, for a fourteen foot telescope, and the other a large double convex, for one of about fifty foot; and upon this, laying the other with its plane side downwards, I pressed them slowly together, says he, to make the colours successively emerge in the middle of the circles, and then slowly lifted the upper glass from the lower, to make them successively vanish again in the same place. The colour which, by pressing the glasses together, emerged last, in the middle of the other colours would, upon its first appearance, look like a circle of a colour, almost uniform from the circumference to the center; and by compressing the glasses still more, grow continually broader, until a new colour emerged in its center, and

thereby it became a ring, encompassing that new colour; and by compressing the glasses still more, the diameter of this ring would increase, and the breadth of its orbit, or perimeter, decrease, until another new colour emerged in the center of the last; and so on, until a third, a fourth, a fifth, and other following new colours successively emerged there, and became rings, encompassing the innermost colour; the last of which was the black spot: And on the contrary, by lifting up the upper glass from the lower, the diameter of the rings would decrease, and the breadth of their orbit increase, until their colours reached successively to the center; and then they being of a considerable breadth, I could more easily discern and distinguish their species than before." And these he found to be in succession from the black central spot as follows, viz. first, blue, white, yellow, and red; then in the next circuit or order immediately encompassing these, were violet, blue, green, yellow, and red; in the third circuit or order were purple, blue, green, yellow, and red; after this succeeded in the fourth circuit green and red; then the fifth of greenish blue and red; next, the sixth, of greenish blue and pale red; and lastly, the seventh, of greenish blue and reddish white: but the colours in the last three circuits he describes as having been very indistinct, and ending in perfect whiteness.

"By looking through the two object glasses," continues he, "I found that the interjacent air exhibited rings of colours, as well by transmitting light, as by reflecting it. The central spot was now *white*, and from it the orders of the colours

colours were yellowish red; black, violet, blue, white, yellow red; violet, blue, green, yellow, red, &c. But these colours were very faint and dilute, unless when the light was trajected very obliquely through the glasses. Comparing the coloured rings made by reflexion, with those made by the transmission of light, I found," adds he, "that white was opposite to black, red to blue, yellow to violet, &c." And as rings of similar colours were observed in bubbles, "blown with water, first made tenacious by dissolving a little soap in it," Sir Isaac Newton endeavoured mathematically to ascertain the different comparative thickneses of air, water, and glass, at which the several circuits or orders of colours appeared as before mentioned, which he has noted in a table prepared for that purpose, and from which this remarkable fact appears, that *similar colours* in the different orders occur, and are repeated over and over again at very great diversities of thickness; a circumstance which, in my humble opinion, proves incontestibly, that though *thickness* might be one, it could not be, as he supposes, the only cause of these repeated variations of colour*. And, indeed, they are obviously to be explained, in the same way as the colours of the prism, the rainbow,

* Sir Isaac Newton seems to have foreseen this objection to his hypothesis, and to have endeavoured to obviate it, by supposing the existence of what he denominated different *orders* of colours; in each of which it was conceived that the red, orange, yellow, &c. required for their production very different thickneses from those which produced the same colours in the other orders: this, however, was but a supposition, improbable in itself, and repugnant to a multitude of facts, which will be mentioned in the course of this work.

&c. and ought not to have been employed towards explaining the causes of *permanent colours* in different substances; or the changes which may be produced in them, by various compositions and decompositions; these being chymical effects, and dependent upon chymical principles. It was, however, at that period, the fashion to ascribe *even chymical effects* to *mechanical causes*: alkalies were supposed to neutralize acids, as the blade of a sword is sheathed by its scabbard; and the most learned physician of his age, soon after, thought it proper to write a *Mesbanical Account of Poisons*. We are not, therefore, to wonder, that Newton himself should have been misled on this subject, since the whole amount of chymical knowledge in his time, had he possessed it, would, like an *ignis fatuus*, have only served to light him astray; as in truth it seems, in some degree, to have done; for, after stating as a proposition, that “the transparent parts of bodies, according to their *several sizes*, reflect rays of one colour, and transmit those of another, on the same grounds that thin plates or bubbles do reflect those rays,” he goes on to mention, “that, by mixing divers liquors, very odd and remarkable productions, and changes of colours may be effected; of which no cause can be more obvious and rational, than that the saline corpuscles of one liquor do variously act upon, and unite with, the tinging corpuscles of another, *so as to make them swell or shrink* (whereby not only their bulk, but their density also, may be changed), or to divide them into smaller corpuscles (whereby a coloured liquor may become transparent), or to make many of them associate into one cluster, whereby two transparent liquors may

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may compose a coloured one:" and laying it down as a proposition, that "the *bigness* of the component parts of natural bodies may be conjectured by their colours," he endeavours, among other things, to explain why the syrup of violets, "by acid liquors, turns red, and, by urinous and alkalizate, turns green;" and for this purpose, he supposes, that "it is the nature of acids to dissolve or attenuate, and of alcalies to precipitate or incrassate;" a supposition which, as acids and alcalies are *chymical agents*², is not true of either of them, in the sense in which Sir Isaac Newton appears to have understood it; though, in another sense, it is partly true and partly false of both; since both are capable of dissolving a great variety of substances, and when a substance is dissolved by either of them, it will most commonly be decomposed and precipitated by the other: but certainly the effect of coagulating, or *incrassating*, which he ascribes to alkalies, is much more frequently produced by acids; though nothing like it is produced by either, in any of the changes of colour, which they occasion to the syrup of violets. It must be also observed, that Sir Isaac Newton has himself admitted, that what he calls "fat, sulphureous, unctuous bodies," possess refractive powers "two or three times greater, in respect of their *densities*, than the refractive powers of other sub-

² When acids "dissolve or attenuate," it is by combining and forming a new compound with the matter so dissolved or attenuated; and when alkalies "precipitate or incrassate," they always produce new compositions and decompositions; changes which are totally foreign to those mechanical effects by which Sir Isaac Newton intended to explain the changes of colour in question.

stances

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In the year 1765, Mr. Edward Hufsey Delaval, F. R. S. communicated some "Experiments and Observations on the agreement between the specific gravities of the several metals, and their colours, when united to glass, as well as of their other preparations," in a letter to the Earl of Morton, then president of the Royal Society: a communication for which the Society bestowed on him the annual gold medal provided by Sir Godfrey Copley. And though Mr. Delaval, in this communication, "treats of the difference of *density* and the *colours* produced by that cause," he, notwithstanding, considers these as connected with "the colours arising from a difference of the size of the colouring particles;" since, "by separating the particles of a coloured substance, they are removed to a greater distance from each other, so as to occupy more space," and, therefore, the substance so affected "must undergo a *diminution of its specific gravity, at the same time* that the size of its particles is lessened." And as Sir Isaac Newton had inferred, that the refractive and reflective powers of bodies were nearly proportional to their densities, and that the least refrangible rays require the greatest power to reflect them, Mr. Delaval conceived, "that denser substances ought, by their greater reflective power, in like circumstances, to reflect the less refrangible rays; and that

that substances of less density, should reflect rays proportionably more refrangible, and thereby appear of several colours, in the order of their density." And, in support of this opinion, he undertook to "give instances of natural bodies, which differ from each other in density, though circumstanced alike in other respects;" and also differ "in colour in the same order as they do in density; the densest being red, the next in density orange, yellow, &c."

"In such an inquiry," says he, "metallic bodies seem to demand our first and principal attention, as their specific gravities have been ascertained by well-known and repeated experiments." Mr. Delaval, however, must doubtless have perceived, that metals, in their pure simple forms, could not suit his purpose of supporting and extending the doctrine of Sir Isaac Newton in this respect; since platina, which is much the heaviest of all metals, and of all known substances, instead of being the *most red*, as upon this hypothesis it ought to have been, is white, like tin, the lightest of metals; and gold, the heaviest of metals after platina, is much farther removed from the red colour than copper, which is so much lighter. And this is also the case of quicksilver, lead, &c. To obviate so formidable a difficulty, he thought it expedient to premise, that, "as the inflammable matter in the intire metals, acts strongly on the rays of light, it is necessary to calcine, or divide them into extremely minute particles, in order to examine separately the action of the calx, or *fixed* matter, on the rays of light." But here, at the very threshold, Mr. Delaval is forced

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PERMANENT COLOURS, &c. 11

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forced to suppose the presence of what he calls inflammable matter, *acting strongly on the rays of light*, and thus producing or changing colours, by properties very different from those of density, and size or thickness of particles. I might here deny, as, in truth, I am very far from believing, the existence of any such matter in metals, which, according to the new and prevailing chymical doctrine, are simple substances, uncombined with any thing like what is here supposed. Admitting however, for the sake of argument, that phlogiston, or inflammable matter, does exist in metals; it must be recollected, that their calcination is not a mere abstraction thereof, since there is no fact in chymistry better ascertained, or more universally admitted, than that every metal in its calcination unites, with a considerable portion of vital air, or its basis, the oxygene³ of the modern chymists, and which (only by variations in the proportions) is capable of producing, with particular

³ By oxygene is meant that substance which, combined with and rendered elastic by heat, or by heat and light, constitutes vital air; or what Dr. Priestley terms dephlogisticated air (first discovered by him in August 1774), the only fluid suited for respiration; the *pabulum vite*, without which the more perfect animals cannot live, even for a few minutes. But as the stimulant or exhilarating effects of this (vital) air would excite, and wear out, the powers of life too much and too rapidly, if it were inspired without mixture, the wise Author of Nature has presented it to us diluted with about three times as much of a different air not respirable by itself, and which, from that circumstance, is now denominated *azote*. These two airs, with a very small portion of carbonic acid gas, or fixed air, and some few accidental or extraneous matters, compose our common atmospheric air. The oxygene, combined with the azote, constitutes, according to their different proportions, either the

cular metals (and with other substances), all the possible variations of colour. Of this however Mr. Delaval takes no account: indeed, when treating of the colours of Mercury, he expressly says, "I have not entered into the consideration of the air, which unites with mercurial colours during their exposure to fire; because it does not relate to *the greater or less division of their particles*, which is the immediate subject of my inquiry." So that, by his own statement, he has overlooked (because it did not suit his hypothesis) the only thing worthy of notice on this subject; since the oxyds or calces of Mercury indisputably receive a variety of colours from nothing but additions, greater or smaller, of that air which he professes to have disregarded; and which having, as he declares, no relation to the greater or less division of their particles, evidently proves, that the various colours assumed by these calces, under the circumstances in question, do not result from any such division of their particles.

But though Mr. Delaval inculcates the necessity of calcining metals, "in order to examine separately the action of their oxyds, or fixed matter, on the rays of light," he does not

the nitrous or nitric acid; the same oxygene united to sulphur by combustion, produces either sulphureous or sulphuric (vitriolic) acid; and, with other bases, it seems to produce most, if not all, of the other acids. With pure charcoal (carbone) it produces carbonic acid (or fixed air), and with inflammable air (hydrogene) it seems now certain that it produces water. This explanation may be useful to such readers as do not happen to be acquainted with the more modern chymistry.

adduce

adduce the colours which they assume when so calcined, as any evidence of the truth of his hypothesis; and indeed he must have perceived them to be absolutely incompatible with it, since the same oxyd, by different degrees of calcination, exhibits very great diversities of colour. And therefore that he might obtain from several of the metals such colours as suited his purpose, he continued to melt them with what he was pleased to think "a proper quantity of the purest glass," and as they, when more or less calcined, and melted or united with a greater or less portion of glass, are capable each of giving several, and some of giving all the colours, it could not be difficult for him to find out, and assign to each metal, as its proper colour, that which it ought to have, upon his supposition that the colours of metals depended on their respective densities. Thus, for example, iron highly calcined, or combined with a large portion of the basis of vital air, (oxygen,) gives a red colour to melted glass; and if the glass be continued in fusion, the oxygen will by degrees be separated, and in proportion to its separation, the colour of the glass will change to orange, yellow, green, blue, and white. And as blue is the colour which suits Mr. Delaval's purpose, he selects and assigns it as the proper colour of iron; and the degree of heat producing it, as the proper one for manifesting the true colours of metals; though in fact he took no means to ascertain what this degree of heat really was; and the effect, or blue colour, would require very different degrees, according to the greater or less degree of calcination which the calx of iron had previously undergone, or, in other words,

words, according to the quantity of oxygene combined with it.

Where every thing is in this way assumed or supposed at pleasure, not only without evidence or probability, but often against both, it must have been easy for Mr. Delaval to prop up an hypothesis which has no foundation in truth. I have now before me a pile of facts and observations respecting the almost infinite variety of colours which different metals assume in different states and circumstances, and which I had arranged for the purpose of shewing more particularly the fallacy of every thing alleged on this subject by Mr. Delaval; but I am constrained to lay them aside, from a conviction, that if I were now to employ them for this purpose, there are few, if any, who would have patience enough to read a statement of them.

Mr. Delaval has quoted, from Glauber's Prosperity of Germany (translated by Packe, 1689), some curious observations respecting the great and surprising variety of colours produced by manganese; and he adds, as from his own knowledge, that "amongst the mineral substances none affords a greater variety of bright colours, especially when it is fused with nitre, or a fixed alkali:" of these he instances a yellow, produced by dissolving manganese in a weak spirit, together with a green, blue, purple, and red, produced by water poured on it; in the first instance cold, and in the others warm, then warmer, hot, and boiling; all which colours he ascribes to different degrees of solution,

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or attenuation, of the particles of manganese. But in truth this and other metallic calces or oxyds, had he properly attended to their various changes of colour, might have shewn him both the fallacy of his own hypothesis, and the road to a better. Manganese is the oxyd or calx of a metal which has so strong an attraction for the basis of vital air, that one of the most excellent of all chymists, Berthollet, says, we may safely consider the whole of what exists in nature to be as in a state of oxydation, or combination with oxygene: when saturated therewith, I mean with the basis of vital air, it is black; and if it be diluted or diffused in melted glass, it becomes purple, or red; and as the vital air diminishes by burning, with the coaly impurities (which it is used for destroying) in glass, it gradually loses its power of producing colours, and leaves the glass transparent and colourless; its colours, however, may be restored by nitre, or any thing affording pure air. The different solutions of manganese, mentioned by Glauber, Mr. Delaval, and many others, undergo their various changes of colour, in consequence of a gradual separation or diminution of their oxygene: and that this is what manganese possesses, and what it loses, in these operations, must be evident to all who are acquainted with the later chymical discoveries, and the very extraordinary purposes to which Mr. Berthollet and others have found it applicable (particularly those of bleaching, and the manufacture of a new and most powerful kind of gun-powder); and which it effectuates solely by the pure or vital air obtained from it. I have already noticed the various colours assumed by the oxyds or calces of iron,

iron, when combined with different portions of the same air, or its basis, the oxygene, which are indeed so many and so diversified, that I remember having been told by Mr. Wedgwood, not long since, that all the fine diversified colours applied to his pottery, were produced only by the oxyds of this single metal; which must have been all of the same, or very nearly the same, specific gravity, and were besides, in these cases, combined or melted with glass, the substance which Mr. Delaval himself thought proper to choose, as being of all others the best for exhibiting what he was pleased to think the true colours of metals. In like manner the oxyds or calces of mercury, lead, silver, bismuth, antimony, &c. assume each a considerable variety of colours (and more especially the two first), by combinations with different portions of oxygene, without any thing like a correspondent variation of density or specific gravity in any of them. Of this Mr. Delaval appears to have been sensible; and in the instance of lead, he endeavours to obviate the evidence which it affords against his theory, by ascribing the various colours of that metal to its "imperfection," which he is pleased to *suppose*, without any, and against every, kind of proof and probability: and then he goes on to say, "it is probable that, during the calcination, lead receives a small portion of *phlogiston* as well as of air; for the affinity between the earth of this metal and inflammable matter is very great, as appears from the readiness with which its solutions and calces unite with phlogistic vapours. The effect of such an union," adds he, "must probably be a change of colour from orange to red; for Sir Isaac Newton has

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shewn, that bodies reflect more strongly in proportion as they possess more phlogiston, and that the less refrangible colours require greater power to reflect them." Here we have another gratuitous and strange supposition of an accession or combination of phlogiston with lead in calcination: I say strange, because those of the adherents of phlogiston who yet continue to believe its existence in metals, have constantly supposed that, in calcination, while they received air, they *lost, instead of gaining, inflammable matter.* But were this extravagant supposition to be admitted as a cause of the changes of colour in metals, how can it be reconciled to any hypothesis which makes their colours depend on their respective densities? Indeed, if the effects which Sir Isaac Newton supposes phlogiston to have on colours were real, and if phlogiston really existed in them, as both he and Mr. Delaval, as well as others, have until lately imagined, it would be difficult to conceive why all metals are not red, or more inclined to redness, than their calces or oxyds. But enough, perhaps too much, has been said, to refute Mr. Delaval's hypothesis, so far as it relates to the colours of metals. Unfortunately, however, for my readers, as well as for myself, he has thought proper, in a larger work⁴, published some time since, to extend the same hypothesis to the colours of animal and vegetable substances; and endeavour to confirm and illustrate Sir Isaac Newton's ideas on this subject, by a variety of experiments, which are represented as instances of changes of colour produced in these substances, by an increase or diminution in the

⁴ Experimental Enquiry into the Cause of the permanent Colours of opaque Bodies. 4to.

sizes of their particles: I am, therefore, compelled reluctantly to extend my own observations a little farther on this matter; and I must begin by complaining of a continuance of *gratuitous* and *fallacious suppositions*, similar to those which I have before had occasion to notice; for when, in operating upon, or with different matters, he professes either to increase or diminish the sizes of their particles, and *to do nothing more*, in order to shew that the changes of colour produced in them, accord with the thick-nesses expressed by Sir Isaac Newton, in the table which I have already mentioned; instead of choosing and employing mechanical means, which alone are suited to produce those effects, and only those effects, he has recourse to mere chymical agents, whose actions in the ways which he supposes must have been almost always doubtful, though their powers of producing other, and very different effects from what he supposes, is most certain. Mr. Delaval, however, adopting Sir Isaac Newton's supposition, that acids always attenuate, and alkalies always incassate, prepared what he considered as a dissolving or attenuating liquor; which "consisted of water, with about an eightieth part of *aqua fortis*:" and when he wanted to lessen the dissolving force of this liquor, instead of weakening it by the addition of water (which would certainly have been the most obvious and unexceptionable expedient), he chose to do it, as he says, by adding "a small quantity of a solution of potash, or some other alkaline liquor;" and thereby produced a new composition, the effects of which must, in many cases, prove different from those of a mere diminution of the supposed

dissolving power of the former liquor. And on the other hand, when he wanted to increase the force of his acid liquor, instead of doing it by a farther addition of aqua fortis (obviously the most proper expedient), he recurs to an addition of *oil of vitriol*; an acid possessing very different properties, and producing very different effects, on a great variety of substances, and particularly on colouring matters; of which I could easily allege hundreds of instances, but shall content myself with only mentioning what is well known, that even the strongest and most concentrated oil of vitriol (used to dissolve indigo for dying the Saxon blue, &c.) does not destroy, or even weaken, its blue colour, though a very weak nitrous acid, or aqua fortis, will wholly destroy it, and convert the indigo to a dirty brown mass, of no use whatever.

Having thus assumed, that acids attenuate, and do nothing but attenuate, the particles of colouring matter; that alkalies incrassate, and do nothing but incrassate, the same particles; that by adding an alkali to his mixture of aqua fortis and water, he weakens, and only weakens, its attenuating force on one hand; and that on the other he increases, and only increases it, by an addition of vitriolic acid; he next provides himself with so much of Sir Isaac Newton's table before mentioned as suits his purpose, by transcribing the different colours of the three first orders, and the different thickesses of air, water, and glass, supposed to produce each of these colours, one after the other; and thus equipped, he proceeds to make experiments upon red infusions of certain vegetables, and generally

generally finds, that with his acid liquor (*i. e.* water with $\frac{1}{3}$ of aqua fortis) the colour continues *red*; that, with the addition of oil of vitriol, to attenuate farther, as he supposes, it becomes yellow; and that if, instead of oil of vitriol, he adds an alkali, to *incrassate*, it becomes a purple. Now it so happens, that though all the other colours are repeated in more than one order, purple is marked but once in Sir Isaac Newton's table, and then it is placed as the first colour of what he terms the third order; and if the red and yellow, from which the purple in question had proceeded, were supposed to be of the same order (as might be expected), then the production of this purple ought, upon Mr. Delaval's theory, to result not from *incrassation*, but from *attenuation*; since the particles of it are stated as near one third less in size, than the particles of the red, and near one fourth smaller than those of the yellow, of the same order: but such is the happy arrangement of this table, and of the several orders of colours, that, by supposing the red in this instance to be the red of the second order, he finds a purple below it in the third, with *only one intervening colour*, and a yellow at *the same distance above*; and these leaps not being very great, he reconciles the appearances to the theory. Indeed, as the second, or middle order in the table, contains all the different colours, and as, excepting one, they are all repeated in the first order, which is above; and also in the third, which is below; hardly any change of colour can happen, which may not be made to accord with Mr. Delaval's hypothesis, he being always allowed to suppose each original or primitive colour to belong to

that order which may be found most convenient; though, in truth, the very admission of different orders or repetitions of the same colours, produced repeatedly by and at *different* thicknesſes, or ſizes, either of particles or plates of matter, is of itſelf a proof (as I have before obſerved) that ſuch colours do not depend on any particular thickneſs of plates or ſize of particles⁵.

I am far from thinking that Mr. Delaval has always choſen the moſt proper matters for fair experiments, or that the experiments themſelves, even on his own principles, were well calculated to aſcertain the truth. But ſuch as they

⁵ When Mr. Delaval, on every occaſion, allots each particular colour to ſome one order, excluſively of the reſt, it would ſeem reaſonable to expect, that he ſhould juſtify this allotment by ſomething beſides his own convenience, and particularly that he ſhould prove that the red, for inſtance, which he places in the ſecond order, exceeds that of the firſt order, in the density and ſize of its particles, exactly in the ſame proportion as $18\frac{1}{2}$ exceeds 9; and that the red which he places in the third order, exceeds that of the ſecond exactly in the proportion of 29 to $18\frac{1}{2}$; and that the other colours of the ſeveral orders differ from each other likewiſe, according to the proportions ſtated as neceſſary for their production in the table which he has adopted from Sir Iſaac Newton. Before this diviſion of colours into orders, and the hypotheſis connected with it, can be admitted to have any other than an imaginary foundation, it ought to be proved, that all the known reds differ from each other in reſpect to the densities and ſizes of their particles, *exactly according to the before mentioned proportions*; and ſo of the oranges, yellows, &c. ſince, in every caſe, the ſlighteſt deviation from the thickneſs or ſize of particles ſtated as eſſential to the production of a particular colour, ought to occasion the appearance of that colour which is next in the ſeries above or below. But nothing like this is any where attempted, nor is there any thing in nature acceſſible to human obſervation, which could in any degree juſtify the attempt.

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are, I can readily point out several, which, on his own improbable, or rather impossible suppositions of mechanical attenuation or incrassation, and nothing else, from chymical agents, cannot be reconciled to his theory, even by the assistance of Sir Isaac Newton's convenient table. The green leaves of the anil and glastrum, he says, "being long steeped in water, their parts are *dissolved* into a blue substance, which is indigo and woad." Now the truth is, that the blue arising from these vegetables is not the result of any *dissolution*, but of an absorption of air during the fermentation which they undergo; and this colour does not manifest itself until there is a beginning *aggregation* and *concretion* of its matter into *larger* particles, which becoming *denser*, as well as *larger*, sink down to the bottom, leaving the water colourless. So that here the change from green to *blue*, is manifestly accompanied with an increase both in the size and density of the coloured particles, which is absolutely incompatible with Mr. Delaval's hypothesis; since, according to the table in question, every change of colour from green to blue is the effect of a *diminution*, not an *increase*, in the size and density of its particles. When the indigo itself (formed into large dry masses) is to be dissolved for dying, by the combined action of *caustic* alkalies, and of particular chymical attractions, or of vegetable ferments, the solution, though manifestly attended with a division or diminution of the coloured particles (as well as a loss of the air absorbed during the first process) becomes green, contrary to the table and hypothesis in question; and in this state it is applied by the dyers to wool, and other substances,

to be dyed; and these, when first taken out and exposed to the air, appear green; but by absorbing, and uniting with a portion of it, they immediately become blue, and in doing so, the divided particles again concrete into larger ones, as must be evident, among other proofs, from this, that the surface of the indigo liquor on which the air has an immediate action, is from that cause always blue; and if we skim off this blue matter from the surface (which is nothing but indigo) it will be found impossible to make it enter the pores of any substance to be dyed, so as to dye a colour therewith; because the particles having regained, and recombined with their proper portion of pure air, or its basis, and with each other, are no longer sufficiently divided and dissolved for that purpose; so that in all these cases, the matter of indigo becomes more dense, and its particles larger, in passing from green, to the more refrangible colour, blue; and the contrary, in passing from blue to the less refrangible colour, green. And this too is the case, when the infusions of rhubarb, turmeric, &c. are made "to descend (as he expresses it) from yellow to orange and red," "by the addition of an alkali," which, whatever he may imagine to the contrary, *dissolves* these colouring matters more powerfully than any acid. Similar objections occur in opposition to the instances which Mr. Delaval alleges, respecting "the changes of Colour which animal substances undergo." Among these, *e.g.* he observes, that cows milk, boiled up with an alkali, changes from white to yellow orange and red; and, as usual, he gratuitously supposes, that, in producing these changes, it acts by *incrassating* or coagulating

coagulating the milk ; though if, contrary to all probability, alkalies were able to do this, we have no reason to conclude that such coagulation would render the milk either yellow, orange, or red, because no such colours appear when it really is coagulated by acids, &c. as in the making of curds and cheese. But surely it cannot be necessary for me seriously to combat such chimeras any longer. The common sense and experience of mankind, if fairly consulted, will condemn and revolt at the idea of making the colours of bodies depend on their weight, or the sizes of their particles ; for it certainly never has been observed that the heaviest substances were red, or the lightest violet-coloured, or that bodies equally heavy were all of the same colour. Different parcels of indigo, for instance, vary considerably as to specific gravity, without any variation of colour ; and therefore it must be very easy to find some of these agreeing in that respect exactly with the colouring matter of cochineal (carmine), which of all colours is the farthest removed from that of indigo : and if Mr. Delaval should allege, that, though agreeing in weight, they differ as to the size of their respective particles, let him correct this difference by the only means suited to do it, without doing more ; I mean by simple mechanical division, trituration, or grinding. Let this be employed upon either of the substances in question as long as he shall think proper, and let us then see whether he can thereby render the colour of indigo red, or that of cochineal blue or violet. Let him also make a similar trial upon mineral ethiops and vermillion ; the one black, and the other of a beautiful red colour, though

though both are composed of mercury and sulphur; and both are, or may be easily rendered of exactly the same specific gravity, by a little alteration in the ordinary proportions of their constituent parts.

Should what I have said on this subject prove insufficient to convince any one of my readers, I only beg that he will follow me, with a mind open to conviction, through the various instances, which, for other purposes, I shall have occasion to state hereafter, of colours produced, or changed by means and in ways that are wholly irreconcilable to the theory in question, and I persuade myself that his doubts and difficulties will be effectually removed, so far as they may relate to the truth or fallacy of Mr. Delaval's hypothesis, of which I mean hereafter to be silent, because I cannot, without pain, support even the appearance of contention. And indeed I feel it necessary to apologize for having so long detained my readers on this subject: I have done it not only from a conviction of the truth of what I have written, but from the belief of its being expedient to refute an hypothesis, incompatible with a considerable part of what I am about to offer to the public; an hypothesis which the name and authority of Sir Isaac Newton had pre-eminently sanctioned; which the learning and talents of Mr. Delaval had rendered plausible; and which even at present is, I believe, generally considered as true, in this and other countries. Should there be found any seeming incivility towards Mr. Delaval, I hope it will be considered as the unguarded effusion of a zeal for truth. Nothing is farther from my wishes

wishes than a personal contention with that Gentleman, though I have thought it necessary to combat an error, capable of obstructing the progress of science. I have never had the honour of his acquaintance, but I have long respected his character and abilities; and though I think he has erred, I also think it may be deemed a matter of excuse and consolation that he has only erred with Newton.

Having, as I think, shewn that the permanent colours of different objects do not arise from their densities, or the sizes of their particles, it becomes me to state such facts and observations as seem best suited to throw light upon this obscure and very intricate subject.

Sir Isaac Newton having found that inflammable substances possessed greater refractive powers than others, in proportion to their densities, says, in his second Book of Optics, that "it seems rational to attribute the refractive power of all bodies, chiefly, if not wholly, to the sulphureous parts with which they abound; for, adds he, it is probable that all bodies abound more or less with sulphurs;" a term by which he intended to distinguish inflammable matters generally. And this great man having also concluded that the permanent colours of natural bodies were analogous to the colours produced by the refractions of thin, colourless, transparent plates, &c. chymists were generally induced to make all colour depend on the principle of inflammability or phlogiston, which, until very lately, was supposed to exist in metals and other substances, where there certainly is no evidence

evidence or appearance of it; and in those cases where the total want of inflammability was manifest, they *confounded* this with the *matter* of heat and that of light; to both of which they ascribed the power of *phlogisticating* other substances, and of thereby producing or changing their colours: a species of confusion suited only to cover and perpetuate ignorance; since every single colour is found to belong both to combustible and incombustible substances, and to neither exclusively. The *combustible* diamond, which Sir Isaac Newton conjectured to be "*an unctuous substance* coagulated," is found to be of almost all the different colours, whilst other gems, though of similar colours, are all *incombustible*. Combustible indigo, and incombustible smalt, are both blue; combustible vermillion and incombustible minium are both red; combustible gamboge, orpiment, &c. are yellow; and so are certain incombustible oxyds of lead, iron, and mercury. But since the existence of phlogiston in metals, &c. has been denied by the pneumatic chymists, they have in most cases attributed the origin and changes of colours to the application or combination of different airs or gazes, and particularly oxygene in different proportions; and it has been supposed that these gazes possessed considerable *refractive* powers, and were *thereby* enabled to produce effects on colours like those which the followers of Stahl had imputed to phlogiston; and Mr. Berthollet, in his recent work on the Elements of Dying, intimates, that "many important observations still remain for those who would follow the steps of that great man (Sir Isaac Newton), and compare the *refracting* powers of the

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the different gazes, and other substances, the constituent principles of which are now known." But from all that I can discern of this intricate subject, it seems to me, that, though the prism, and other transparent colourless substances, in different forms, shew us the different colours of the several rays of light, by *separating* them from each other, in consequence of their greater or less refrangibility, or disposition to be "turned out of their way, in passing out of one transparent body or medium into another," yet I am persuaded that the *permanent* colours of different bodies, or substances, *are not produced by mere refraction*, and that Sir Isaac Newton was misled by analogy when he extended his discoveries and conclusions respecting the transient colours resulting from the refractions of light by pellucid colourless substances, to the permanent colours of various kinds of matter; since the latter evidently depend on other properties, which determine, or occasion the reflection or transmission of some particular sort or sorts of rays, and an absorption or disappearance of the rest; and these I conceive to be certain *affinities*, or *elective attractions*, existing in or between the differently coloured matters and the particular sorts or rays of light so absorbed or made *latent*; and of which many instances and proofs will, I think, be found in the subsequent parts of this work. Next after the diamond and amber, we find that spirit of turpentine, lintseed oil, olive oil, camphor and alcohol, or rectified spirit of wine, possess greater refracting powers, in proportion to their respective densities, than any of the other substances contained in Sir Isaac Newton's table, and yet they

they are all *permanently destitute of colour*; a fact which does not seem to indicate any connexion between the refractive power of a substance and its natural *permanent colour*. Nothing seems to act so powerfully and extensively in producing and changing those affinities, or elective attractions, from which the permanent colours of different substances arise, as pure vital air, or its basis, the oxygene; which indeed seems to owe its elastic, or aërial form, to a portion of light as well as heat. Scheele demonstrated that gold, silver, &c. were revived from their oxyds by the contact of light; and Mr. Berthollet has proved, that, in producing this effect, the light occasions a separation of oxygene, in the form of pure vital air. Light also, by giving elasticity to oxygene, separates it from various other substances, to which it would otherwise remain united, under, perhaps, the greatest degrees of heat. A bottle filled with oxygenated muriatic acid, improperly called dephlogisticated marine acid, if it be exposed to the light, lets go its oxygene, and becomes common muriatic acid, but if wrapped in black paper, and exposed to the sun, it suffers no change; and if heated in the dark, it will fly off in the form of oxygenated muriatic gas, without any decomposition of its oxygene.

We are at this time well acquainted with the constituent parts of the acid of nitre: it undeniably consists of what the pneumatic chymists term azote (phlogisticated or nitrous air), rendered acid by its combination with a certain portion of oxygene; or the basis of vital air. When the azote and the oxygene are combined

bined in a certain proportion, the acid or compound is colourless, as we see it in aqua fortis, or nitric acid: but if this colourless acid, in a transparent glass vessel, partly filled, be exposed to the rays of the sun, or the light of a fire, an alteration will take place in the proportion of its ingredients; since the light will combine with a part of the oxygene, and cause it to become elastic and fly off, and the azote will consequently predominate in the remainder; which, merely in consequence of this predominance, will assume first a yellow, then an orange, and afterwards a high vivid aurora, and even a red colour, intensely affecting the sight. But if the glass vessel containing the colourless nitric acid, were filled with it, no such change of colour would take place by any degree of exposure to the sun's rays or other light; because, in this case, there would be no sufficient space or room to allow of a separation and escape of the oxygene. When nitrous acid has been made to assume the colours as before mentioned, if the glass vessel containing it be hermetically sealed and kept for some time in the dark, the oxygene, by losing its light, will lose its elasticity; and being again reabsorbed by the nitrous acid, the latter will become colourless, as before. Mr. Keir mentions an orange-coloured nitrous acid, which, by long keeping, became green, and afterwards of a deep blue; and Bergman says, that if, to a concentrated red nitrous acid, one fourth part of the quantity or measure of water be added, the colour will be changed to a fine green, or to a blue, by the addition of an equal measure of water, and that double its quantity of water will destroy the colour. Here then

we have an example of all the various colours produced by the two species of air which compose our atmosphere (almost wholly) when deprived of their elasticity, and mixed in particular proportions with more or less dilution by water.

In the same manner, colourless nitric acid, when applied to wool, silk, fur, or the skins of animals, their nails, horns, &c. renders them all not only yellow, but orange, and even aurora-coloured. Mr. Berthollet thinks these changes are produced by a kind of combustion; but I am persuaded they are the result of a combination of the oxygene with the azote, which he has proved to be a constituent part of all animal substances; they being exactly similar both in their nature and origin, to the changes of colour produced as before mentioned in the nitrous acid. Were these colours the effect of combustion, why are they not likewise produced in the same manner upon linens, cottons, and vegetable substances, which contain either little or no azote, but a great portion of the basis of charcoal, and ought therefore to be more liable to be acted upon in the way of combustion, than animal substances?

Long before the properties of the several kinds of air were known, many changes of colour had been noticed as produced by the application or action of light; and indeed its effects are so remarkable, in a multitude of cases, that no one can doubt of its powerful agency in these and other respects. The only thing to be ascertained on this point is, whether the colours
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which accompany or require the application of light, result directly from a combination of it with the coloured substance, or indirectly from its particular action in occasioning a separation of airs, or their bases (and particularly of the oxygene), or by favouring a combination thereof with the coloured matter. Mr. de Luc maintains, that light enters mediately or immediately into the composition of a considerable number of solids, and of all liquids and expandible fluids, particularly the æriform; and it seems reasonable to conclude, that it must greatly influence many physical and chymical phenomena. That able chymist Mr. Chaptal, found that the rays of light directed particularly upon certain parts of glasses, containing solutions of different salts, caused them to crystallize upon those sides which were in contact with the light, and no other. Many substances absorb and retain large portions of light, as appears by their emitting it in the dark; this is the case of the Bolognian stone, and of many other natural as well as artificial compositions; among the latter, Mr. Canton's phosphorous (composed chiefly of calcined oyster shells) imbibes and retains the light so strongly, that, after being exposed to it for only a few seconds, it continues to be luminous even at the end of six months. Almost all animal and vegetable substances are found to emit light in certain stages of putrefaction, or decomposition, and therefore it may be presumed to have been previously combined with some of their parts; but how it acts, or whether it acts at all immediately, in producing the colours of any object, seems yet uncertain; though we know that it does contribute greatly

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to the production or change of colours in a multitude of mineral, vegetable, and animal substances; in some cases, by combining with the basis of vital air (oxygen), and separating, by rendering it elastic; and in others, by promoting the action and union thereof, upon or with particular substances. It seems difficult to ascertain the particular affinities by which sometimes the one, and sometimes the other, of these effects is produced: perhaps they depend on causes to which chymical knowledge, in its present imperfect state, cannot reach.

From the experiments of Beccari, Meyer, Schulze, Scheele, and Sennebier, it appears that muriate of silver (horned silver), which is nearly of a pearl white, changes to a violet colour, and from thence to a black, in the space of a very few minutes, when exposed to the sun's rays in a transparent glass; and this change Sennebier ascribes solely to the action of light; since, as he maintains, the muriate of silver will invariably retain its whiteness, though exposed either to heat or cold; and in a moist or a dry air, or in *vacuo*, if secured from the accession of light, and of what he calls phlogistic vapours (probably sulphurated, hydrogenous gas), and that it loses its whiteness only by the application of light, and then only in proportion to its quantity or intensity; so that when the sun's rays are copiously applied by a lens, the muriate of silver is rendered violet coloured in a single second. By covering the muriate of silver with four thicknesses of white paper, its whiteness was preserved; one, two, and three thicknesses retarded, but did not prevent its finally

finally becoming violet and black. Mr. Sennebier found that the different rays of light, under the same circumstances, coloured the muriate of silver with different degrees of celerity; *i. e.* the violet rays in 15 seconds, the purple in 23 seconds, the blue in 29, the green in 37, the yellow in 5 minutes and 30 seconds, the orange in 12 minutes, and the red in 20; but the rays of the three last colours would not, as he relates, produce such a dark violet colour in any length of time, as was thus quickly produced by the more refrangible rays. I have also witnessed most of these, and some other changes of colour, taking place in muriated or horned silver, and which may, I think, be satisfactorily explained, by considering that this preparation is the oxyd or calx of that metal, united only to a very small portion of either oxygene or muriatic acid, which the light renders elastic, and thereby separates such a portion of it as to produce an incipient reduction or revival of the metal, and with it the dark colours which silver always manifests in that state; and in confirmation of this, I need only mention what I have several times observed, that though muriated silver, placed at the bottom of a colourless glass vessel, nearly filled with water, was made violet coloured in about two minutes, by the weak light of a room, having a single window only, and in a cloudy day; yet a direct application of the sun's rays for many days produced no change of colour, when the muriated silver was covered with muriatic acid instead of water; because, in this case, nothing like a revival of the silver could take place, whilst so much uncombined muriatic acid remained in contact with it, and

ready to supply the place of any which might be separated by the sun's rays.

It is curious to observe the different degrees of force and celerity with which, according to Sennebier, the different rays of light change the colour of horned silver, *exactly* in proportion to their degrees of refrangibility; an effect which must be ascribed to a greater affinity between the least refrangible ray and the muriatic acid, in consequence of which the former more readily combine with and extricate or separate the latter from the silver to which it was united.

A solution of silver in the nitric acid likewise changes colour by the action of light, and becomes black *thereby*, as well as by the application of inflammable substances, of calcareous earth (chalk), and every thing else which can separate a sufficient portion of the oxygen. It also gives the skin a black colour, which cannot be effaced, but by a removal or change of the skin itself: it tinges the hair, nails, and other animal substances, in like manner, because they occasion a separation of so much of the oxygen as is necessary for that purpose.

Mercury dissolved in nitric acid, being washed with water, affords a yellow oxyd, which, when exposed to the light in a transparent colourless glass vessel, will become black on the side to which the light is applied, even where the vessel is filled with water; because, as in the case of horned silver, the light extricates a part of the oxygen; this yellow oxyd being a preparation of mercury, with but a very small proportion of acid.

acid. The red precipitate, and several other preparations of mercury, have their colours changed even under water, by similar means. The white or colourless solution of mercury, by the nitric acid, when applied to animal and inflammable substances, tinges them purple and black, in the same way, and from the same cause, as they are tinged by the solution of silver. Similar effects happen with the solution and oxyd of bismuth, which last is therefore used to blacken hair when mixed with pomatum. Almost all the other metals afford instances of changes of colour more or less remarkable, depending upon the accession and separation of oxygene; and in many of which light has a considerable influence in promoting one or other of these effects. In all the instances lately mentioned, however, blackness was produced by a separation of air from the metallic basis; but there are others in which it results from the addition or accession thereof. Arsenic, as Mr. Chaptal mentions, when first sublimed, is of a shining grey, or steel colour, but blackens speedily in the air ("noircit promptement a l'air"); and he likewise observes, that "manganese, precipitated by an alkali from its solution, was found to be a whitish gelatinous substance, which soon changed colour, and became *black*, by the contact of air; that, having been a witness of this phenomenon, he could only attribute it to the absorption of oxygenous gas, and found this to be the case, by shaking the white precipitate in glasses filled with that gas, by which the black manifested itself in one or two minutes, and a considerable part of the gas was found to have been absorbed." *Elemens de Chymie*, tom. ii. p. 260.—

The preceding instances relate to mineral and inorganic substances, though in the two last it must be owned, that the influence of light (the immediate object of consideration) is not very evident; and therefore I shall proceed to notice some of the more remarkable effects of that element, in producing the colours of vegetable and animal substances. Ray, in his *Historia Plantarum*, printed in 1686, vol. i. p. 15. appears to have discovered, by several experiments and observations, that the green colour of plants depended chiefly upon the influence of light: he had found that they were *green*, whilst vegetating under a transparent glass bell exposed to the light, and that when growing in obscurity under an opaque vessel, they lost their green, and acquired a pale whitish yellow; their stalks, at the same time, becoming long, slender, and feeble, and their leaves small. And these effects he ascribed to the want of light, rather than of either air or heat. “*Nobis tamen non tam aer quam lumen, luminisve actio coloris in plantarum foliis viridis causa esse videtur.*”—“*Ad hunc autem colorem inducendum non requiritur cœlor,*” &c. Mr. Bonnet has since confirmed Ray’s conclusions upon this subject, and added several curious facts, resulting from a variety of experiments related in the fourth and fifth volumes of his works: but it is Mr. Sennebier who has done most, and carried his inquiries farthest respecting it, as appears by his “*Memoires Physico Chymiques sur l’Influence de la Lumière Solaire,*” &c. in 3 vols. 8vo.

It is now well ascertained, that vegetables, growing in the light, give out the oxygenous gas
(pure

(pure vital air); and Dr. Ingenhouz, by a great number of experiments, has proved, or conceives himself to have proved, that in the dark they give out the carbonic acid gas (fixed air); though this has been doubted by others, and particularly by Mr. Sennebier, who conceives, that, in these cases, it was the pure air vitiated by some disease or decomposition of the plant itself: Dr. Ingenhouz, however, in his last publication, adheres to his former opinion, and supports it with new facts and arguments. Be this, however, right or wrong, there is no room to doubt but that healthy plants, growing in the light, decompose both water and carbonic acid gas; and, appropriating to themselves the hydrogen, or inflammable air (which is a constituent part of water), and the carbonaceous matter, or basis of the carbonic acid, with perhaps a small portion of the oxygen, they emit the rest in the form of vital air, which the light seems to separate, by combining with and rendering it elastic, in the same manner as it separates the oxygen from the calces or oxyds of metals, &c. But when plants vegetate in obscurity, no such separation can take place: indeed the water imbibed by the plants seems not to be properly decomposed, unless its living powers be aided by the stimulus of light, and by its affinity for the oxygen. There is, therefore, an accumulation of this latter substance, and a want of inflammable air to compose the resinous matter, by which the green colour of the plant is produced; and this colouring matter being very sparingly formed, and at the same time combined with an excess of oxygen (which generally weakens or destroys vegetable colours), the plant, instead of its natural greenness, exhi-

bits only a pale straw colour. Mr. Sennebier found that plants, in this state, received a deeper green, and in less time, by exposure to the violet rays of light, than to those which were less refrangible, as was the case in colouring the muriate of silver. He also found that plants left to vegetate without light, under vessels filled either with azote (phlogisticated air), or with hydrogen (inflammable air), did not lose their green colour, as when surrounded by common atmospheric air. In carbonic acid (fixed air) they soon perished. Dr. Ingenhouz also observed, that on mixing a little inflammable air with either the common or the vital air in which a plant was growing, under a transparent glass, the green colour of the plant soon became deeper. In these cases there seems to have been an aspiration or absorption of the inflammable air, affording an increase of the resinous colouring matter.

Mr. Sennebier also found, that the red tinctures of orcanette*, safflower, kermes, gum lac, and cochineal, were made yellow by exposure to the sun's rays; and the tincture of dragon's blood was thereby deprived of all colour: in these cases the alcohol, or spirits of wine, assisted the action of the sun's rays in decomposing the several colouring matters, probably by combining with their oxygene; because it was found that the *aqueous* infusions of orcanette, kermes, and cochineal, suffered no change by the like exposure; though indeed the infusions of safflower, dragon's blood, and gum lac, were changed by it; perhaps because they contain a

* *Anchusa tinctoria*. LIN.

refinous matter which might have co-operated with the rays of light, in the same way as the spirit of wine is supposed to have done. Mr. Sennebier observed, that the petals of damask roses afforded a kind of brick colour to spirits of wine, when put into it; and that this, by a few minutes exposure to the common light, became of a fine violet-colour; which, however, was soon destroyed, by a direct application of the sun's light, unless when a few drops of some of the strong acids were added; in which case, the colour withstood the sun's rays for several months. From these instances I conclude, that the colour of the roses depends on a certain proportion of oxygene; that the light, aided by the attraction which spirits of wine, as well as other inflammable matters, have for oxygene, separates it and destroys the colour; but that these effects are prevented, as might be expected, by the addition of acids containing and affording a supply of oxygene. And that this was the fact, seems evident from this observation, made by Mr. Sennebier, that when the petals of the roses had been rendered white by imparting their colour to the spirit of wine, they regained it on being taken out, and exposed to the air, even in a dark place; though they did it much quicker in the light; but not at all in a vessel containing only azote, surrounded by quicksilver, even when aided by an immediate application of the sun's light; which clearly proves, that the restitution of oxygene was indispensably necessary to the restitution of their colour. In the same way sulphureous acid whitens roses, by abstracting and depriving them of their oxygene; and the sulphuric acid restores the colour, by restoring

the oxygene⁶. Mr. Sennebier also found the red skins of peaches to whiten in spirits of wine, like the petals of roses, and, like them, to regain their colour by exposure to the air; as did also the red skins of plumbs. He likewise observed, that the water-colours used by painters, if covered by a solution of fish-glue or isinglass, and then varnished, withstood the action of the sun's rays much longer than if varnished without the fish-glue; which last seems to prevent the varnish from co-operating with the light in extricating the oxygene of the colouring matters, as, from its inflammable nature, it would do, if in immediate contact with them. The preceding are examples of colours produced, changed, or destroyed by the action or affinity of light, exerted in separating, by giving elasticity to, the oxygene or basis of vital air. There are many other cases, however, in which the affinity of light is very differently exerted, and in

⁶ The sulphureous or volatile vitriolic acid, not being saturated with oxygene, is disposed to attract it from other matters in contact with it; and by so doing, it not only whitens roses, but silk, wool, and other substances, rendered yellow by being united to a certain portion of oxygene: and these substances, being so whitened, may again be made yellow by the application of oxygenated muriatic acid, which will restore to them that portion of oxygene of which they had been deprived. Hence it appears, that the application of oxygene, which so powerfully bleaches linen, is equally efficacious in producing a contrary effect on silk and wool; I mean that of destroying their whiteness, and rendering them yellow. And these opposite effects arise from a difference in the substances acted upon by the same agent, the whiteness of wool and silk evidently depending upon the absence of oxygene, and that of linen and cotton upon its presence; perhaps upon their being completely saturated with it.

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which that element, instead of decomposing the oxygene, and carrying it off from particular matters, contributes rather to attract it, and promote its combination with them, probably by uniting itself to the same matters (in consequence of some particular affinity), and forming, together with the oxygene, a triple compound. The green colour of the leaves of plants resides in a resinous substance, which being dissolved and extracted by spirits of wine, produces a green tincture; and Mr. Sennebier having exposed this to the rays of the sun, in a clear transparent glass, but half filled, he found, upon repeated trials, that the colour was generally destroyed in about twenty minutes, and a yellowish substance was precipitated to the bottom; which I conceive to have been the colouring matter saturated with oxygene: but if the glass was completely filled with the green tincture, and closely stopped, Mr. Sennebier found, that the strongest action of the sun's rays upon it, during four months, was not sufficient even to weaken in any degree the green colour, because all oxygene was excluded, and the rays of light, without it, were unable to effect any change. If azote (phlogisticated air) was inclosed in a vessel partly filled with this green tincture, the latter suffered little or no change by long exposure to the direct action of the sun's light; but if, instead of this, he substituted pure vital air, the green colour was most rapidly destroyed. Mr. Sennebier also found, that the dark red juice of black cherries very soon lost its colour, when exposed to the sun's rays, but that a tincture of those cherries in spirit of wine preserved its colour, in the same circumstances; the spirit of wine, as I conceive, affording a covering and defence to
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the colouring matter of the cherries against the action and farther combination of oxygene or vital air. Here the effect was directly opposite to that of roses, lately mentioned. There are many other instances of absorption of oxygene promoted by the action of light: many of these I shall have occasion to mention hereafter for other purposes, and therefore will content myself at present with noticing two experiments made by Mr. Berthollet. In the first, he "inverted, over mercury, a bottle half full of the green solution (employed by Mr. Sennebier), and exposed it to the light of the sun; when the colour was discharged, the mercury was found to have *risen in the bottle*, and consequently vital air had been absorbed; the oxygene having united with the colouring matter." In the second experiment, he "placed a tincture of turnsol, in contact with vital air, over mercury, both in the dark, and exposed to the light of the sun; the former continued unchanged for a considerable length of time, and the vital air had suffered no diminution; but the other lost much of its colour, became red, and the air was in a great measure absorbed, &c.

In the same manner that plants, first shooting out of the earth, are white, so negro children, when first born, are likewise of that colour, but by exposure to light and air, they in a few days become black; and as far as I can judge from what I have seen of the effect, it seems to result from a combination of air, with a particular matter or basis, composing a part of the reticular membrane under the skin, and fitted by Nature to become black in this way, as that of the European is to remain white, or that of the
aborigines

aborigines of North America to be brown, &c. The blackness of the negro children is found, by observation, to be considerably hastened by early exposure to strong light, which seems to favour the absorption, or combination of oxygen; an effect which is not surprizing, since, by many of Mr. Sennebier's experiments, the light was found to act in this way through coverings of greater thickness than those which oppose its access to the reticular membrane in negroes.

The action of light upon the human European skin, is also strongly manifested by the production of tan and freckles; of which the latter appear likewise to reach as far as the reticular membrane. These effects are the most remarkable in sea voyages, and other situations where the light is copiously reflected, especially by water, though without any increase of heat. In like manner the hair of kittens, puppies, &c. though fitted by nature to become black, is, immediately after birth, only of a brownish black colour, which gradually darkens externally, or as far as it is exposed to the air and light, but no farther; for I have found the blackest cats and dogs; even in old age, to have that part of their hair which is nearest the skin, and most secluded from air, particularly towards its roots, only of a brownish black colour, very different from what is seen at the ends or points.

Mr. Sennebier mentions, upon the authority of Schéele, that the *nereis lacustris* is red whilst living in places accessible to the sun's rays, and white when living in obscurity. And M. Dorthes (see *Ann. de Chymie*, tom. ii.) affirms, that

that most of the larvæ of insects inhabiting the interior cavities of animals, as well as of woods, fruit, the earth, &c. are white, and that having forced many of them to live under transparent glasses, exposed to the light, their whiteness was gradually changed for brown colours; and that the tree frog, which generally lives in the shade, being forced to live in a situation exposed to the sun-shine, changed his colour from a yellowish, to a very dark green. In these last instances it does not appear certain whether the light produces the changes of colour which have been just mentioned, by occasioning an abstraction or an addition of oxygene, but from what we know of its effects, in cases apparently similar, we may at least conclude that it acts in one or the other of these ways. *Yellow* silk, according to Mr. Poivre's account, taken from the cocoons and exposed to the sun, soon becomes perfectly white; and the same happens to ivory, if exposed in like manner, after it has become yellow. These effects are similar to those which occur to white cotton garments, and to white lead paints, which notoriously become yellow, if deprived of the free access of light and air for any length of time, but are again rendered white, by whatever restores to them the oxygene which is wanting to maintain their whiteness.

I have now noticed the principal facts respecting the action of light in producing or changing the colours of minerals, vegetables, and animals; and as far as our knowledge extends, it does not appear warrantable to conclude that light contributes to these effects, otherwise than by its affinity with oxygene, which, (affinity,) under some circum-

circumstances, and with the aid perhaps of other unknown affinities, sometimes separates and renders the oxygene elastic by uniting with it, and at other times occasions the combination of an increased portion thereof with the coloured substance. This last effect is what Mr. Berthollet seems exclusively to insist upon, as occasioning, either with or without the aid of light, all the changes and injuries to which animal and vegetable colouring matters are liable; and he deems the action and effects of oxygene in these cases to be similar to those of *combustion*. "In considering the effects of air on colours (says he), it is necessary to make a distinction between those produced by metallic oxyds, and those produced by the colouring particles," meaning those of a vegetable nature; the modifications of the former are "entirely owing, continues he, to different proportions of oxygene;" but I have been led by observation, he adds, "to form a different opinion of the latter," with which the oxygenated muriatic acid had exhibited different phenomena, sometimes discharging their colour, and producing whiteness, but most frequently rendering them yellow, fawn, or root-coloured, or brown, or black, according to the intensity of its action: and he remarks, that he had found, by comparison, that when the colouring particles were rendered yellow, root-coloured, or brown, by the oxygenated muriatic acid, effects were produced similar to those of combustion; and that they were "owing to the destruction of the hydrogen, which, as it combines with oxygene more easily, and at a lower temperature than charcoal does, leaves the latter *predominant*; so that the *natural colour of charcoal* is more

more or less blended with that which before existed';" And as "the light of the sun considerably accelerates the destruction of colours," he concludes that it ought, if his theory be well founded,

7 Mess. Lavoisier, Berthollet, and other pneumatic chymists, seem to consider the *black* colour of charcoal as naturally belonging to the vegetable matter from which it is formed, and not as the result or effect of combustion. To me, however, charcoal seems to be a kind of vegetable *oxyd*, consisting of the carbonaceous basis, united to a certain portion of oxygene, enough to render this basis black (as it occasions the blackness of manganese), but not enough to saturate and convert it into carbonic acid gas. Hard woods contain so great a portion of the basis of charcoal, that if it really existed therein, with its black colour, previous to combustion, it is impossible to conceive how they should ever appear white, yellow, red, &c. since in dying, &c. we find, that laying other colours upon a black ground, only increases the blackness. Neither do I think that this blackness is the only circumstance in which charcoal differs from its basis, or the state in which the vegetable part thereof existed previous to combustion: on the contrary, I am persuaded that its oxydation, or combination with oxygene, gives it new and very remarkable properties. Mr. Fourcroy has informed us (see *Ann. de Chymie*, tom. v.), that the aqueous extracts of several colouring matters, by being left for a considerable time exposed to air, acquired and combined with a considerable portion of oxygene, and thereby assumed new colours, and at the same time became themselves much more fixed and permanent than before; which seems to be the case (though in a greater degree) of the vegetable basis of indigo and that of charcoal. This last is indeed never converted into charcoal, but by such a degree of heat as must necessarily occasion its combination with oxygene (which never can be wanting, even in close vessels, because it exists in the air vessels, and other parts of all vegetables); and when this conversion is made, the charcoal is rendered infinitely more indestructible than any other vegetable matter, as it will resist the combined action of sun, air, moisture, &c. for hundreds of years; and indeed it can hardly be destroyed but by such farther combustion as will change it into carbonic

founded, "to favour the combination of oxygene, and the combustion thereby produced *."

In thus ascribing the decays of vegetable and animal colouring matters in general to effects or changes similar to those of *combustion*, Mr. Berthollet, in my opinion, has gone much further than is warrantable by facts. It cannot, I am persuaded, be his intention that we should apply the term of combustion to alterations which result from a simple addition of oxygene, to colouring matters, without a destruction or separation of any of their component parts; though a great many of the decays and extinctions of these colours evidently arise only from such simple additions of oxygene. The nitric, sulphuric, and other acids containing oxygene, have the power not only of weakening, but of extinguishing, for a time, the colours of many tinging matters; not however by any effect which can properly be denominated a combustion, but rather by a change in their several affinities or attractions, for particular rays of light in preference to other rays;

nic acid gas. This indestructibility, as well as the black colour of charcoal, seem therefore to result from the combination of oxygene with its basis. Were not this the case, and did it really exist with its black colour naturally in vegetables, why do we not find it remaining intire after the other parts of vegetables are separated or destroyed by fermentation, putrefaction, &c.? and why does it dissolve and rot with them undistinguished, and contrary to what happens when it exists separately, in the form of charcoal? and why, when in this form, will it not recombine with matters similar to those separated from it, and enter with them into fermentation, &c. as it surely ought to do if it had acquired no new property, and only been left in a distinct form, by the simple abstraction of those matters?

* Elements of the Art of Dying, chap. iii.

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but none of their parts being destroyed, or carried away, the addition of an alkali, or of calcareous carbonate, will generally undo such alteration, and restore the original colour, by decomposing and neutralizing the acid or oxygene which had caused the alteration. Of this hundreds of instances might be given, it being the case of almost all vegetable or animal colouring matters; it will however be sufficient to mention, what most people have seen, that ink, dropped into a glass of diluted nitric, vitriolic, or other acid, will lose its colour, and that it may be again restored by adding a suitable portion of vegetable or fossil alkali; and that this may be done several times with the same ink, and therefore the change, or loss of colour, could not have been the effect of combustion. If however this ink had been fixed, by dying in the substance either of wool, silk, linen, or cotton, and the substance so dyed had been dipped into a glass of diluted acid, as before mentioned, a considerable part of the colouring matter would have been dislodged, and separated from the dyed substance, by its affinity with the oxygene or acid; and though no combustion had taken place, the colour so separated and lost, could not be again restored without a second dying: and this loss of colour would be similar to what frequently happens to colours from exposure to sun and air, by which they are gradually weakened, many of them without any other change of tint than the simple diminution of their original body, or quantity of colouring matter; and this continuing in the more fugitive colours, particularly that of turmeric, the cloth is soon left as white as before it had been dyed, without any thing like combustion having ever taken place in it,

it, or in the matter with which it was dyed^s. Mr. Sennebier exposed a great variety of woods to the action of the sun and air, and found all their colours very soon affected. The white woods were generally made brown, and the red and violet changed either to yellow or black. Guaiacum was rendered green; the oak and the cedar were whitened, as were the brown woods generally; effects which certainly do not resemble those of combustion, any more than the bleaching of wax and tallow by exposure to air.

The colour of each particular substance evidently depends on its peculiar constitution, producing in it a particular affinity or attraction for certain rays of light, and a disposition to reflect or transmit certain other rays; and in this respect it may doubtless suffer very considerable

^s That colours are not generally impaired by any thing like combustion, as Mr. Berthollet supposes, may be presumed from this fact—that there are but few of them, which the common muriatic acid does not injure as much as either the nitric or the sulphuric; and as there can be no combustion without oxygene, and as the common muriatic acid either contains none (which is Mr. Berthollet's opinion), or what it does contain is confessedly combined with it, by an affinity too powerful to be overcome by any known substance or means, it necessarily follows, that the oxygene (if it contains any) cannot be liberated so as to act in the way of combustion upon any other matter; and therefore when the common muriatic acid changes or destroys the colours in question, it changes or destroys the affinities upon which they depend, by producing effects different from those of combustion; and as the changes which it produces on colours are in most cases similar to those produced by the nitric, sulphuric, and other acids known to contain oxygene, it seems reasonable to conclude that these also act upon colours, by producing other effects than those of combustion.

changes from the action or combination of oxygen, without any effects similar to those of combustion. And indeed the changes of colour which arise from the access of vital or atmospheric air, seldom resemble those which the mere predominance of blackness (the supposed natural colour of charcoal) would produce; though this may have been the case with the colouring matter of brown or unbleached linen, upon which Mr. Berthollet's experiments were principally made.

But whether the action of vital air, or its basis, in promoting the decays of colours, ought to be denominated a combustion or not, I am confident that, at least, some of them are liable to be impaired, not so much by an accession of oxygen, as by the loss of it; an effect, of which I have already enumerated several examples, among animal and vegetable, as well as mineral substances, deriving their colours from a combination with certain portions of oxygen; and to these I might add several other examples.

Hook and Lower long since noticed the difference of colour in arterial and venal blood; and it has been since proved, by numerous experiments, that the fine vermilion colour of the former, is produced solely by vital air, which it is capable of acquiring even through bladders, the coats of blood vessels, &c. And very recently, Mr. Hassenfratz seems to have proved (see *Ann. de Chymic.* tom. ix.), that as this fine red colour is gained by a dissolution of oxygen in the arterial blood, so it is lost, and the dark colour of the venal blood restored, by a separation

separation of the oxygene, in consequence of its forming a new combination with the hydrogene and carbone thereof.

That the blue colour of indigo absolutely depends upon a certain portion of oxygene, has been already mentioned, and I shall hereafter give some curious illustrations of this fact, from which it will appear that a solution of indigo, by losing its oxygene, may become as pellucid, and, excepting a very slight yellowish tinge, as colourless as water, and afterwards speedily return through all the shades of yellow and green to its original deep blue, by exposure to atmospheric or vital air. Similar to this is the fact long since observed by the Abbe Nollet, of the tincture of archil-orchella employed to colour the spirit of wine used in thermometers, and which after some time loses its colour, but soon recovers it again upon being exposed to atmospheric air. And this also happens to the infusion of turnsol, and to syrup of violets, which both lose their colours when secluded from air, and regain them when placed in contact with it. Many other examples of the like effects might be mentioned here; but to avoid repetitions, I beg leave to refer my readers to subsequent parts of this work, in which I shall have occasion to instance various animal and vegetable colours, produced solely by the contact of vital or atmospheric air; and some others, which, when given by dying or callico printing to wool, silk, cotton, &c. though unable to sustain a single day's exposure to the sun and air without manifest injury, were found to receive none from the action of strong nitric or sulphuric acids, but, on the contrary,

were preserved by being wetted with them, and even with oxygenated muriatic, and sulphuric acids. But the same colours, if covered with lintseed oil, were found to decay more quickly from exposure to the sun and air, than if uncovered. These colours therefore could not owe their decays to the contact or combination of oxygene, because they were not only unhurt, but benefited by its concentrated powers in the nitric, the oxygenated muriatic, and sulphuric acids; and also because they were soonest impaired when defended from the access of oxygene, by being covered with lintseed oil. Probably the decays of these colours were occasioned by a loss of at least some part of the oxygene which was necessary to their existence, and which the lintseed oil assisted in depriving them of, by its known affinity with vital air.

In forming systems, we are apt to draw general conclusions from only a partial knowledge or view of facts. And this even Mr. Berthollet seems to have done, not only in ascribing the decays of vegetable and animal colours, exclusively to effects similar to those of combustion, but also in representing the oxygenated muriatic acid as an accurate test or measure for anticipating, in a few minutes, the changes which these colours are liable to suffer, by long exposure to the action of sun and air; for though it doubtless is true that the oxygenated muriatic acid, in weakening or destroying colours, gives up to them more or less of the oxygene, which it had received by distillation from manganese; and that, by this new combination of oxygene, those affinities for particular rays of light, upon which their
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their colours depend, are liable to be destroyed; it is nevertheless true, that the changes of colour so produced are no certain indication of those which the combined influence of light and air will occasion upon colours in general; there being, as I have already observed, and as I shall more fully explain hereafter, several colours which are very speedily destroyed by the latter of these causes, though they resist the strongest action of the oxygenated muriatic acid, without any kind of injury.

Mr. Berthollet well knows, since nobody has contributed more to ascertain, how much the properties of oxygene are diversified by each particular basis to which it unites; and it does not therefore seem warrantable to imagine that its action will not be modified by a basis so powerful as that of the common muriatic acid, or that the united properties of both should represent or resemble those of atmospheric air upon colours any more than they do in the lungs by respiration, where, instead of supporting life, they would instantly destroy it.

To ascertain, by well-directed experiments made upon each particular ingredient of the materia tinctoria, in what ways, or by what changes, the colours of each are liable to be injured, would doubtless contribute most essentially towards perfecting the art of dying; since it would not only help us to discover more clearly by what properties each is fitted to absorb or combine with particular rays of light, and reflect others, but also through what particular defects some are more fugitive than others: and having

made these discoveries, we might probably be led to the proper means of obviating or correcting such defects, so as to render fugitive colours permanent, and improve those which are already considered as such.

Under this persuasion I lately projected various experiments upon the colours of different dying drugs, calculated to ascertain the effects of light upon them, *in vacuo*, as well as when surrounded or covered by the several kinds of air, or by water, or alkohol, or the different acids, oils, or varnishes, both in warm and in frosty weather; and also the effects of the like agents and circumstances upon the same colours, placed in obscurity; meaning, as far as might consist with the present state of chymical knowledge, and the defects of our senses, instruments and means when applied to such intricate and minute subjects, to discover what each colour had either lost or gained by the influence or contact of these several agents, and the changes of colour resulting in every instance from such loss or gain; and flattering myself with the hope of being able in these ways to contribute greatly towards improving the knowledge and philosophy of colours. But having been called abroad during that part of last Summer which was most suitable to the greatest part of these experiments, I have found it necessary to defer most of them to the next favourable season, when they will be undertaken and prosecuted with as much care and expedition as may be compatible with my other unavoidable avocations; and an account of their results will be published in some of the subsequent volumes of this work. The subject

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is, however, sufficiently extensive and important to merit the attention and exercise the talents of abler philosophers.

But until further discoveries shall have been made, we are only authorised to conclude, that the permanent colours of natural bodies do not depend upon their thicknesſes, ſizes, or the denſities of their ſeveral parts or particles, but upon certain affinities or attractions (chymical or phyſical) by which they are diſpoſed to abſorb and conceal ſome of the rays of light, and to reflect or tranſmit other rays, giving the ſenſations or perceptions of their reſpective colours; that the contact of light greatly contributes towards producing theſe affinities or attractions: but it only does this (as far as we yet know) either by promoting a combination or a ſeparation of the baſis of vital air in the different coloured or colouring ſubſtances. But though moſt of the changes of colour, in permanently coloured bodies, evidently depend on changes in their reſpective portions of oxygene, I am far from thinking that this cauſe operates excluſively in all caſes, or that chymical knowledge is yet far enough advanced to juſtify even an attempt towards a complete hypotheſis reſpecting theſe moſt abſtruſe and moſt intereſting phænomena.

Should any one aſk how oxygene acts in producing theſe affinities or attractions for particular rays of light, I ſhall only answer with M. de Buffon, that they who require the reaſon of a *general effect*, do not conſider either the infinite extent of Nature's operations, or the narrow limits of human underſtanding.

C H A P. II.

*Of the Composition and Structure of the Fibres of
Wool, Silk, Cotton, Linen, &c.*

“ Ubi natura definit nobis incipiendum.”

BEFORE I treat of the communication or production of colours by dying or callico printing, it will be proper to inquire concerning the particular natures and differences of wool, hair, silk, cotton, linen, and hemp, upon which these operations are usually performed. The three first are animal, the three last vegetable substances, differing from each other in their constituent parts and chymical properties, as well as in structure and organization. Mr. Berthollet has done much towards ascertaining the chymical differences and properties of these matters; and the former has been found, by his experiments, to contain a large proportion of azote (of which the latter possess but very little), and also a much larger proportion of hydrogen, than what belongs to vegetable matters: and as the azote and hydrogen readily assume an elastic form, the wool, hair, and silk, in which they abound, have less adhesion between their constituent parts, or molecules, than what exists between those of cotton, linen, and hemp, and are therefore more strongly disposed, than the latter, to combine with other substances, when brought into contact with them; and it is probably in consequence of this disposition that wool, hair, and

and silk, manifest stronger affinities or attractions for colouring matters generally, than cotton, linen, or hemp^{*}. They are also more readily decomposed, or injured by acids, alkalis, and other chymical agents, which ought therefore to be more sparingly used in the dying of animal, than of vegetable substances: it being found that the sulphuric, nitric, and even the muriatic acids decompose wool, hair, and silk (by separating either their azote or their hydrogen, or both in some cases), and at the same time destroy, or greatly weaken the texture and connexion of their several fibres; and that alkalies prove equally injurious, by combining with them: though silk is indeed not so liable to be acted upon in these ways, because it partakes in some degree of the vegetable nature.

It is from the superior chymical affinities, or attractions existing in wool, hair, and silk, for colouring matters, that the facilities with which these substances receive, and permanently retain colours, principally result; though something is doubtless to be ascribed to the differences of conformation existing between their fibres and

^{*} e. g. Cotton and linen will neither of them receive any colour by the same preparation, and in the same liquor, which dyes wool or woollen cloth scarlet. This is every day seen by the cotton edges of long ells, &c. which remain white after the rest of the cloth is become scarlet. M. Dufay even caused a piece of cloth to be manufactured, of which the chain was wool, and the woof cotton. This was afterwards fulled, that both might be brought into a similar state of preparation; and the cloth being then dyed by the usual process, the woollen threads contained in it received a good scarlet, whilst the cotton remained white.

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those of cotton, linen, and hemp, which I shall notice under their several heads. And,

I. *Of Wool.*

The value of this substance, and its fitness for the different kinds of manufacture, depend on the length and fineness of its fibres; of which ample information may be found in a Memoir written by M. d'Aubenton, and printed among those of the Royal Academy of Sciences for the year 1779. The business of spinning, and that of weaving, do not properly fall under my consideration; but the operation of fulling deserves to be noticed, as being connected with circumstances which seem to have some influence in the dying of wool and cloth. Fulling, according to Sir William Petty (See Spratt's History of the Royal Society), "is making the cloth to become thicker, with the diminution of its other dimensions, and the covering of its threads, so as that the cloth shall seem to be translated from the likeness of a tela (all of whose threads appear) to that of a hat which has no threads at all; for, by the way, the making of a hat (continues he) is the making of a tela, without spinning or weaving, by a kind of fulling." "This thickening," adds he, "is made by the shortening of threads; this shortening of threads by twisting of them; this twisting by the heat of the mill (for such effect visibly hath heat on hair, &c.); this heat of the mill is excited rather by an unequal motion, than by fire and scalding water, as in hats; and the constriction is furthered by oatmeal, earth, and urine, which are less potent than

than the astringent powders and liquors used about hats."

M. Monge has, however, lately given a better account of operations of felting and fulling (see *Ann. de Chymie*, tom. vi. p. 300, &c.), by which it appears, that the "shortening of threads" is not the effect of heat, or of any astringent power whatever, but an effect resulting from the external conformation of the fibres of wool, furr, &c. which appear to be formed, either of small lamina placed over each other, in a slanting direction, from the root towards the end or point of each fibre, like the scales of fish, lying one over the other, in succession, from the head to the tail; or of zones, placed one upon another, as in the horns of animals; from which structure each fibre, if drawn from its root towards the point, will pass smoothly through the fingers; but if it be drawn in a contrary direction, from the point towards the root, a sensible resistance, and tremulous motion will be felt by the fingers. This conformation disposes the fibres of wool to catch hold of each other, and as they cannot recede, when acted upon by other bodies, they naturally advance, by a progressive motion, towards, and beside each other, from the end towards the root; a disposition which is very inconvenient to spinning, and therefore the wool is greased, that the asperities arising from this structure of its fibres may be thereby covered, or sheathed, as a covering of oil sheaths those of a fine file. But the wool being manufactured, and the grease no longer useful, it is removed by scowering, not only for the sake of cleanliness, but that it may
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not frustrate the process of dying. The cloth is therefore carried to the fulling mill, and there subjected to the action of large beetles, with fullers earth and water, by which the cloth is not only scoured, but its fibres, in consequence of the structure just described, being made to conjoin, and advance toward, and beside each other, become shorter, and more closely connected, or felted together, the warp and woof losing in extent, but gaining proportionably in thickness.

The lamina, or zones, under consideration, afford many interstices in the fibres of wool, suited to receive and contain the particles of colouring matters, when applied to them in the operation of dying; but these interstices being small, and the fibres of the wool naturally elastic, no colour can be conveyed into these cavities, until they are diluted by hot or boiling water; whereas silk, cotton, and linen, are made to receive colours without heat, as permanently as with it. And this difference manifestly arises from the smallness of the interstices in which the colouring particles are deposited in wool, and the elasticity of its fibres, which make it necessary to dilate them by hot or boiling water; and as the colouring particles are only made to enter and deposit themselves by an artificial dilatation, it follows that, when this ceases, the filaments will again contract to their former size, upon the colouring matters so introduced, and hold them much more strongly than they are likely to be held in other substances whose interstices are large enough to receive colouring particles without being dilated, and

and which, therefore, cannot be supposed ever to contract and compress them in the same way: and this difference, joined to the superiour chymical attraction of animal fibres for colouring matters, will sufficiently explain why many colours dyed upon wool and hairs, prove so much more durable than upon cotton or linen. Wool is naturally covered with a kind of oil, which would obstruct the process of dying, and is therefore to be removed, by what is called scow-ering; an operation sufficiently known. Wool, when dyed in the fleece, takes up much more colouring matter than when spun, and much more than when wove into cloth. It is also more or less penetrated, according to the fineness of its own texture, and the particular nature of the colouring matter with which it is dyed. The very coarse wool taken from the thighs and tails of some rams and sheep, being never made to receive colours without difficulty; and indeed the very finest cloth is never thoroughly dyed scarlet, it being always found white within when cut.

Wool taken from different breeds of sheep, in various countries, is naturally of different colours; as white, yellow, reddish, and black. Formerly, all the flocks in Spain, excepting those of Andalusia, were of this last colour, it having been preferred for wearing by the native Spaniards; and this natural brownish black is even at this time manufactured, and worn constantly by some religious orders in Roman Catholic countries. The white wool, however, is now almost universally preferred to every other, as being susceptible of receiving better colours by dying,
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than any of those which are natural. Manufactures of wool, though superfluous to man in a state of nature, seem to be, of all others, the most important in civilized society.

II. *Of Silk.*

The phalena, bombyx, or silk-worm, seems first to have become an object of human care and attention in China, where it subsisted naturally from the earliest times. According to the annals of that country, the wife of the emperor Hoang-Ti first occupied herself in collecting the cocoons which were found on trees, and in winding off their silk, which was afterwards brought into use.

Another species of this insect is also found in China (the phalena atlas of Linnæus); its cocoons are said to be larger, and their silk much stronger, than those of the other; but being difficult to wind, it is commonly spun.

From China, silk was carried first to Hindostan, and afterwards to Persia; but it does not seem to have been known in Greece or Rome until about the time of Augustus, when its nature and origin being but little understood, very confused ideas were entertained of it; and during several ages it was so scarce, as only to be bought by, at least, its weight in gold; and hence the emperor Aurelian, as is related, refused the pressing solicitations of the empress for a robe of silk, alleging that it would prove too costly. In the year 555, however, two monks came from India to Constantinople,

bringing with them a considerable number of silk-worms, and instructions for their management and propagation, as well as for collecting, winding, and manufacturing their silk; in consequence of which, establishments were formed at Athens, Corinth, and Thebes, for profiting by this acquisition; and about the year 1130, Roger king of Sicily, returning from his crusade to the Holy Land, brought with him, from Athens and Corinth, several prisoners acquainted with the manufacture of silk, and management of silk-worms; and to avail himself of their knowledge in these respects, he caused suitable manufactories to be established for them at Palermo and Calabria, and his example was soon followed in other parts of Italy, as well as in Spain; and it was attempted to be followed in England afterwards by James the First, who repeatedly urged the planting of mulberry trees, and the propagation of silk-worms, in the strongest terms to his subjects, though with but very little success.

The fibres of silk are naturally covered with a kind of varnish, or gummy substance; and almost the whole of what we know in Europe, is moreover tinged of a yellow colour, which it is necessary to remove, as well as the varnish, for most of the purposes to which silk is applied. This is commonly done by submitting it to the action of soap, in circumstances which are already sufficiently known, and which Mr. Berthollet has so fully described, as well as some other means for answering this double purpose, that I shall add nothing more on this subject.

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When silk has been freed from both its gummy varnish and its yellow colour, it is sometimes necessary to whiten it still farther, by the fumes of sulphur applied to it, and confined in a stove. But though sulphureous acid gas, applied in this way, readily whitens the silk, and thereby renders it more fit to exhibit lively colours, a portion of sulphur adheres to it, which must be removed by soaking and agitation, for a considerable time, in warm water, that it may not tarnish the colours intended to be given by dying; an effect which sulphur generally produces, both to those of wool and silk. The lustre so much desired in colours dyed upon silk, seems, in a great degree, to result from the gloss and polish of its surface, which acids, alkalies, and other chymical agents (particularly the solutions or oxyds of tin), contribute to impair, and are therefore to be sparingly used.

Silk, in its disposition to receive and retain colours for dying, seems to partake of a middle nature between that of the animal and vegetable substances: by its abundance of azote and hydrogen, it possesses, like wool, a strong attraction for colouring matters; but its fibres having neither a similar organization, nor an equal degree of elasticity, it is capable of imbibing colours, like linen and cotton, without any previous dilatation of its pores by hot water, but, like them, it parts with the colours so imbibed the more easily, in consequence of this natural openness, or the want of contraction, in its pores; though, upon the whole, colours dyed in silk are more lasting than when dyed in linen
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and cotton, on account of its greater affinity with colouring matters, resulting from its animal nature.

In the year 1709, Mr. Bon, First President of the *Chambre de Comptes* at Montpellier, communicated, to the Royal Society of that city, a discovery which he had made of a new kind of silk, from the very fine threads with which several species of spiders entwine their eggs; which threads were found to be much stronger than those composing the spider's web. They were easily separated, carded, and spun, and then afforded a much finer and stronger thread than that of the common silk, though somewhat less glossy. They were also found capable of receiving all the different dyes with equal facility. Three ounces of this new silk made a pair of durable stockings of the largest size; and as the spiders were much more prolific, and much more hardy than the silk-worms, great expectations were formed of benefit from this discovery. M. Reaumur therefore took up, and prosecuted the inquiry with zeal. He conceived that, when spiders were artificially multiplied for the production of silk, it would be impossible to provide them sufficiently with flies, their natural food. This, however, was soon removed, by his finding that they would subsist very well upon earth worms chopped, and upon the soft ends or roots of feathers. But a new obstacle arose from their unsocial propensities, and proved unsurmountable; for though at first they seemed to feed quietly, and even work together, several of them at the same web, yet they soon began to quarrel, and the strongest devoured

the weakest, so that of two or three hundred, placed together in a box, but three or four remained alive after a few days; and nobody could propose to keep and feed each separately. M. Reaumur found their silk to be naturally of different colours; particularly white, yellow, sky blue, grey, and coffee-coloured brown. See Hist. & Mem. de l'Acad. Royale des Sciences, ann. 1710.

III. Of Cotton.

The genus of cotton-bearing vegetables (*Gossypium*, LINN.) consists of several species, and a multitude of varieties, most of which are herbaceous annual plants; but some are perennial shrubs or trees; they differ also from each other in the length, fineness, softness, flexibility, and colours of the cotton which they severally produce. The climate is moreover supposed to have considerable influence on the texture and quality of the different species of cotton; that which grows nearest the equator being generally the most esteemed. There are two species which seem to have belonged originally to Siam; the first is white, and of a long fine staple, capable of being spun into very fine threads: this species has been transplanted to the West Indies a considerable time; the other is naturally of that brownish buff colour which it retains in the pieces of cloth manufactured from it, and denominated *nankins*. The shrub on which it grows has been lately introduced at Jamaica, and, I believe, at the Bahama Islands. But a more remarkable species of cotton, naturally of a crimson colour in the pod, has been mentioned by different travellers as growing in Africa,

Africa, and principally in the Eyeo country. Mr. Clarkson informs us, that a small specimen of it was brought home (to Great Britain) in the year 1786. He adds, that "the value of this cotton would be great both to the importer, and the manufacturer of muslins: the former would immediately receive eight shillings for a pound of it, and the latter would gain considerably more by his ingenuity and taste." The cottons of Cyprus, and other parts of the Levant, are generally whiter, and their filaments more dry and elastic, than those of other countries; and these peculiarities have been supposed to render the former particularly suited to reflect, and permanently retain what is called the Turkey red.

The manufacture of cotton has lately become one of the most important in Great Britain. It was computed that twenty millions of pounds weight of unmanufactured cotton were imported into Great Britain in the year 1786.

The structure of the fibres of cotton has not been well ascertained. Lewenhoeck, by microscopical examinations, found each of them to have two sharp sides; and it seems to be owing to this circumstance, or to their possessing some asperities like the filaments of wool, that cotton greatly irritates and inflames wounds, ulcers, &c. if applied to them instead of lint, from which they differ totally in this respect; and perhaps the particular structure which occasions this difference, also occasions some in the conformation and number of their pores, to which alone can be ascribed the disposition which cotton mani-

feels to admit and retain colours better than linen, though not so well as wool and silk, because its vegetable nature does not afford it equal attraction for colouring matters.

M. le Pileur d'Apligny endeavoured to explain the cause why colours are less durable when dyed in silk, cotton, and linen, than in wool, by supposing that the pores of the three first of these substances were smaller than those of wool; and that therefore colouring particles could not enter into them so easily and freely as into those of wool. But the very reverse of this supposition seems true, there being little difficulty in making silk, cotton, or linen imbibe colours, even when topically applied cold, without any artificial dilatation of their pores, which is necessary in the dying of wool. The real difficulty, therefore, is not in making them imbibe, but in making them retain the colouring particles when imbibed; because, being admitted so readily into their undilated pores, they cannot be afterwards compressed and held therein by any contraction of these pores, as is done in those of wool. We know that it requires twice as much cochineal to produce a crimson on silk, as on wool; which is a proof that it can take up a greater quantity, and consequently that its pores are at least sufficiently large and accessible: we know also, that unbleached cotton is always preferred for dying the Turkey red, it being found to retain the colour most permanently; doubtless because its pores or interstices are less open before than after the operation of bleaching. This is also the case of raw or unscoured silk, which, as the ingenious Mr. Henry of Manchester

Manchester observes, is " more easily and permanently dyed than that which has passed the above described process" of whitening and scouring: and indeed the openness of the pores of cotton and linen, and their consequent readiness to imbibe, both colouring particles, and the earthy or metallic bases employed to fix most of them, are circumstances upon which the art of callico printing is in a great degree founded. To prepare and dispose cotton for receiving colours by dying or callico printing, it is usually boiled in water, with a portion of vegetable or fossil alkali, for about two hours, and afterwards rinsed in clean water; or it may be soaked in water, acidulated with about one fiftieth of its weight of sulphuric acid, and afterwards rinsed thoroughly in a clear stream of water.

Mr. Berthollet has so well treated of the preparation of flax, and its conversion into linen; and this, as a subject of dying, so nearly agrees with cotton, excepting the circumstances already noticed, that I need offer nothing more respecting it.

C H A P. III.

Of the different Kinds and Properties of colouring Matter, employed in Dying, Callico Printing, &c.

“ Toutes les choses visibles se distinguent ou se rendent
“ desirable par la couleur.”

COLBERT. *Instruction general pour la Teinture, &c.*

BY colouring matter, I understand a substance which possesses or acquires a power of acting upon the rays of light, so as either to absorb them all, and produce the sensation of black; or only to absorb particular rays, and transmit or reflect the others, and thereby produce the perception of that particular colour which belongs to the ray so transmitted or reflected.

Among minerals, the colouring matter of each is distributed equally to all its parts; but in animal and in vegetable substances, it generally exists in particular parts, or particles which are capable of being extracted for the purposes of dying, &c.

Colouring matters possess peculiar chymical properties, which distinguish them from all other kinds of matter; for besides their several affinities with particular rays of light, they have others which render them susceptible of being acted upon, and modified by a variety of chymical agents, as well as of forming permanent combinations with the filaments of wool, silk, cotton, linen, &c. But in respect of these affinities,

nities, colouring matters also differ essentially from each other, and must therefore be applied in different ways, and with very different means, to produce permanent colours in other matters. The art of dying is founded upon a knowledge of the particular properties and affinities of these matters, not only as far as they relate to the substances intended to be dyed, but also as far as they are connected with the operations of other agents, by which they are liable to be acted upon either during the process of dying, or afterwards.

Many species of animal and vegetable colouring matters suffer nearly similar changes from the action of acids, alkalies, and other chymical agents; from which it may be presumed, that there is something of a common or similar nature in the constitution of many of them. But though it would be highly useful to establish general principles and conclusions on this subject, we are not yet furnished with the necessary facts; and whilst this continues to be the case, it will be best to wait, or rather seek for more knowledge, and avoid fallacious suppositions or explanations.

Sir Isaac Newton supposed coloured matters to reflect the rays of light; some bodies reflecting the more, others the less refrangible rays most copiously; and this he conceived to be the true, and the only reason of their colours. Mr. Delaval, however, has lately maintained (see 2d vol. of the Memoirs of the Philosophical and Literary Society of Manchester), "that, in transparent coloured substances, the colouring matter does not reflect any light; and that
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when, by intercepting the light which was transmitted, it is hindered from passing through substances, they do not vary from their former colour to any other colour, but become entirely black :” and he instances a considerable number of coloured liquors, none of them endued with reflective powers, which, when seen by *transmitted* light, appeared severally in their true colours; but all of them, when seen by *incident* light, appeared black : which is also the case of black cherries, black currants, black berries, &c. the juices of which appear red when spread on a white ground, or otherwise viewed by transmitted, instead of incident light; and he concludes, that bleached linen, &c. “ when dyed or painted with vegetable colours, do not differ in their manner of acting on the rays of light, from natural vegetable bodies; both yielding their colours by transmitting through the transparent coloured matter the light which is reflected from the white ground :” it being apparent, from different experiments, “ that no reflective power resides in any of their component parts, except in their white matter only,” and that “ transparent coloured substances, placed in situations by which the transmission of light through them is intercepted, exhibit no colour, but become entirely black.”

“ The art of dying, therefore (according to Mr. Delaval), consists principally in covering white substances, from which light is strongly reflected, with transparent coloured media, which, according to their several colours, transmit more or less copiously the several rays reflected from the white substances,” since “ the transparent

transparent media themselves reflect no light; and it is evident that if they yielded their colours by reflecting, instead of transmitting the rays, the whiteness, or colour of the ground on which they are applied, would not in any wise alter or affect the colours which they exhibit."

Having had reason to differ from Mr. Delaval on some other points, I am happy in being able to agree with him on this, so far as relates to transparent colouring matters, when applied to wool, silk, &c. without the interposition of any earthy or metallic basis. But when any such opaque basis is interposed, the reflection is doubtless made by it, rather than by the substance of the dyed wool, silk, &c. and more especially when such basis consists of the white earth of alum, or the white oxyd of tin; which by their strong reflective powers greatly augment the lustre of colours. There are, moreover, some opaque colouring matters, particularly the acetous, and other solutions of iron, used to stain linen, cotton, &c. which must necessarily themselves reflect, instead of transmitting the light by which their colours are made perceptible.

It has been already mentioned, that when the rays of light are separated from each other by the prism, in consequence of their different degrees of refrangibility, they produce a perception of seven distinct colours, with all their intermediate shades; and that these are all equally simple and primitive. There is, however, this peculiar property belonging to the red, yellow, and blue colours, whether prismatic or permanent; that they are incapable of being produced, like
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all the rest, by the combination of any other colours. Blue and red will compose a purple; blue and yellow, a green; red and yellow, an orange, &c.; but none of these, by any composition, will produce either the blue, yellow, or red: these last, therefore, are in all cases simple or uncompounded; but all the others may be, and in reality are, sometimes simple and sometimes compounded; not only those which are merely prismatic colours, but those which exist naturally in bodies, or are communicated by painting, dying, &c. Iron, as has been already mentioned, will, by different degrees of oxydation, produce all possible varieties of colour; and these colours will be all simple or uncompounded; and so will the purple of gold, the green of copper, and the other colours found in the several oxyds of metals. This is also the case of the violet and purple dyed from logwood; of the green colouring matter of the leaves, &c. of vegetables; of the green inner bark of elder, the green juice of the berries of the *rhamnus catharticus*, &c.; and of the orange dyed from the quercitron bark, as will be hereafter mentioned. And among animal colours, numerous instances may be alleged of simple or uncompounded greens, oranges, purples, and violets: even the yellowish white liquor of the *purpura*, *murex*, and *buccinum*, from which the celebrated Tyrian purple was produced, passes quickly through all the shades of yellow, green, violet, and purple, upon being exposed to the sun in atmospheric air; and these must necessarily be deemed simple, not compound colours. But on the other hand, dyers, painters, &c. daily produce orange, green, purple, and violet,
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by mixtures of the blue, yellow, and red : nor is it necessary that these should be intimately mixed, since wool dyed of any two of these colours, if spun and wove, will uniformly appear like the simple homogeneous colour which, in the series of prismatic colours, lies between them. It has been repeatedly found in dying compound colours, as for instance, green, that laying a permanent blue over a fugitive yellow, does not defend the latter, or make it in any degree more lasting, but that it will decay (leaving the blue in full strength) as rapidly as if no blue had been applied ; and therefore we may presume, that the fibres of the dyed stuff were but partly covered with the yellow colouring matter, and that when the blue came to be afterwards added, its particles found spaces sufficient to lodge themselves collaterally, without being placed upon the yellow particles.

Several attempts have been made to arrange and class the different species of colouring matters employed for dying and callico printing ; but none seems to accord with, or give any just ideas of, their several natures and properties. Mr. Berthollet indeed alleges sufficient reasons for not dividing these matters, as Mr. Macquer did, into extractive and resinous, and also for not making their effects depend, as Mr. Pœrner has done, upon the mucilaginous, earthy, saline, resinous, or oily parts of which they were supposed to be compounded, but without proposing any suitable arrangement of his own.

To me, however, colouring matters seem to fall naturally under two general classes ; the first including

including those matters which, when put into a state of solution, may be permanently fixed, and made fully to exhibit their colours in or upon the dyed substance, without the interposition of any earthy or metallic basis; and the second, comprehending all those matters which are incapable of being fixed, and made to display their proper colours without the mediation of some such basis. The colours of the first class I shall denominate *substantive*; using the term in the same sense in which it was employed by Bacon Lord Verulam, as denoting a thing solid by, or depending only upon, itself; and colours of the second class I shall call *adjective*, as implying that their lustre and permanency are acquired by adjection upon a suitable basis.

Of substantive colours, I shall first notice the animal, then the vegetable, and lastly the mineral.

CHAP. IV.

Of Substantive Animal Colours.

“Tyrioque ardebat murice lana.”

VIRG.

THE most celebrated and precious of all the ancient dyes, was the purple, obtained from particular kinds of univalvular shell-fish; of which the best, and almost the only accounts, handed down to us, may be found in the writings of Aristotle and Pliny, and especially of the latter,

latter, in whose time the purple dye seems to have attained its greatest perfection. They, in different places, have briefly mentioned the different shell-fish from which the dye was obtained, how they were caught, and how their colour was prepared and applied to wool; but these accounts, from their brevity, were better suited to excite, than satisfy, an enlightened curiosity.

Pliny, in the 36th chapter of his seventh book, ranges the different shell-fish, giving the purple, under two genera: the first comprehended the smaller species, under the denomination of *Buccinum*; so called from their resemblance to a hunting horn; and the second included those denominated *Purpura*. These *Fabius Columna* conceives to have been also distinguished by the generic name of *Murex*; though others suppose this to have signified all the different species generally.

Many fabulous accounts have been given of the first discovery of the purple liquor, and its application as a dye, which seems to have been made at Tyre, about fourteen or fifteen centuries before the Christian æra; and the Tyrian dye, in consequence thereof, became highly celebrated in different countries.

The several species of shell-fish under consideration, were found as well on the European as the African coasts of the Mediterranean; and they appear to have given colours of different shades; and the liquors yielding these colours were frequently mixed with each other, in vari-

ous proportions, to produce other variations of colour: one, or at most two drops, of this liquor were obtained from each fish, by extracting and opening a little reservoir, placed in the throat. But to avoid this trouble, the smallest species, as we are informed by Aristotle and Pliny, was generally bruised whole in a mortar; and this, according to Vitruvius, was often done with the larger; though the other fluids of the fish must have necessarily debased the colour in some degree. The liquor, when extracted, was mixed with a considerable portion of salt, to preserve it from putrefaction, and was then diluted with five or six times as much water, and kept moderately hot, in leaden or tin vessels, for the space of ten days, during which the liquor was often skimmed, to separate all impurities; after which the wool, being first well washed, was immersed and kept therein for five hours, then taken out, carded, and again immersed, and continued in the liquor until all the colour was exhausted. To produce particular shades of colour, nitre, urine, and a marine plant, called Fucus, were occasionally added. Several of these varieties of colour have been particularly mentioned by ancient writers. One of them, which was very dark, seems to have been a violet, inclining towards the reddish hue; "*Nigrantis rosæ colore subluces.*" Plin. lib. ix. sect. 50. Another, and less esteemed, was probably a kind of crimson; but the most esteemed, and that in which the Tyrians particularly excelled, resembled coagulated blood; "*laus ei summa in colore sanguinis concreti.*" Plin. sect. 62. There was, moreover, a fourth kind, known in later times; an account of which may be

be found in Perrault's translation of Vitruvius: Pliny says, the Tyrians first dyed their wool in the liquor of the purpura, and afterwards in that of the buccinum; the purple mentioned in Exodus, chap. xxv. was also twice dyed. Wool which had received this double Tyrian dye (diabapha), was so very costly, that, in the reign of Augustus, each pound of it sold for 1000 Roman denarii (about 36l. sterling). But lest this should not sufficiently exclude the use of it, from all who were not invested with the highest dignities, laws were made, inflicting severe penalties, and even that of death, under the later emperors, upon all who might presume to wear it. The art of dying this colour came at length to be practised only by a few individuals, appointed and maintained by the emperors for that purpose; and it being interrupted about the beginning of the 12th century, all knowledge of it was soon after lost, except what remained in the more ancient writings; and during several ages this celebrated dye was considered and lamented as an irrecoverable loss.

It happened, however, that Mr. William Cole of Bristol, being at Minehead about the end of the year 1683, heard, from two ladies there, of a person living at a sea-port in Ireland, "who made considerable gain by marking, with a delicate durable crimson colour, the fine linen of ladies and gentlemen, sent him for that purpose;" and that this colour was "made by some liquid substance taken out of a shell-fish." Mr. Cole being a lover of natural history, and having his curiosity thus excited, went in quest of these shell-fish; and after trying various kinds without

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success,

success, he at length found considerable quantities of the buccinum on the sea-coasts of Somersetshire, and the opposite coasts of South Wales; and after many ineffectual endeavours, he at length found the colour in a "white vein, lying transversely in a little furrow, or cleft, next to the head of the fish;" which, says he, "must be digged out with the stiff point of a horse-hair pencil, made short and tapering, by reason of the viscous clamminess of the white liquor in the vein, that so by its stiffness it may drive in the matter into the fine linen, or white silk," intended to be marked. Letters or marks made in this way, with the white liquor in question, "will presently," adds he, "appear of a pleasant green colour, and if placed in the sun, will change into the following colours, *if* in the winter, about noon, if in the summer, an hour or two after sun-rising, and so much before setting (for in the heat of the day in summer the colours will come on so fast, that the succession of each colour will scarce be distinguishable;) next to the first light green, will appear a deep green;" "and in a few minutes this will change into a full sea green; after which, in a few minutes more, it will alter into a watchet blue; from that, in a little time more, it will be of a purplish red; after which, lying an hour or two (supposing the sun still shining), it will be of a very deep purple red; beyond which the sun can do no more." He remarks, however, "that these changes are made faster or slower, according to the degree of the sun's heat;" "but then," adds he, "the last and most beautiful colour, after washing in scalding water and soap, will (the matter being again put out into the sun or wind

wind to dry) be much a differing colour from all those mentioned, *i. e.* a fair bright crimson, or near to the Prince's colour; which afterwards, notwithstanding there is no styptic to bind the colour, will continue the same, if well ordered, as I have found in handkerchiefs that have been washed more than forty times; only it will be somewhat allayed from what it was after the first washing." Mr. Cole found, that, when linens marked with the white liquor in question were taken out of the sun, when the colours had only reached any one or more of the before mentioned shades, and shut up between the leaves of a book, the colour or colours made no farther progress whilst so shut up, but remained always of the same shade. He also found, that whilst linen marked with the white liquor was drying by exposure to the sun, *for the first time*, it would always "yield a very strong scetid smell (which divers who smelt it could not endure), as if garlick and assafoetida were mixed together;" and this happens in cases where linen, after being marked, had been shut up in a book for twelve months before it was exposed to the sun's rays. He also found, that the colour in linen which had been dried, and washed immediately after being marked, was better than when it had lain fourteen months between the leaves of a book, unwashed.

Mr. Cole sent some of the first linen marked by him in this way, to Dr. Plot, then one of the Secretaries of the Royal Society, in November 1684; and it was soon after shewn to King Charles the Second, who admired it greatly, and desired that some of the shell-fish

might be collected and brought to town, that he might see the liquor applied, and the successive changes of colour which it underwent; but before this could be done, the king died; and though Mr. Cole's letter (from which the preceding extracts were made) was in the following year published, in the fifteenth volume of the Philosophical Transactions, and excited the attention of philosophers in most of the countries of Europe, it does not appear that any attempt was made to revive the practice, along with the knowledge, of dying the ancient purple.

After an interval of twenty four years, Mr. Jussieu found a small species of buccinum, in form resembling the garden snail, on that part of the French coasts which is washed by the Atlantic ocean, and presented some of them, in the year 1709, to the Royal Academy of Sciences at Paris; and in the following year, the celebrated Mr. Reaumur found great quantities of the buccinum on the coast of Poitou; and he moreover observed, that the stones, and little sandy ridges round which these shell-fish had collected, were covered with a kind of oval "graines," some of which were white, and others of a yellowish colour; and having collected and squeezed some of these upon the sleeve of his shirt, so as to wet it with the fluid or liquor which they contained, he was agreeably surprized, in about half an hour, upon finding it stained of a fine purple colour, which he was unable to discharge by washing. This was done upon the sea-shore. He next collected a quantity of these grains, and carrying them to his apartment, bruised and squeezed different parcels of

of them upon bits of linen; but to his great surprise, after waiting two or three hours, no colour appeared upon the spots wetted with their liquor. Unable to conceive the reason of this disappointment, and having almost determined to return again to the sea-shore, and repeat his experiment in the same place as before, he chanced to perceive some purple spots, occasioned by drops of the liquor which had accidentally fallen upon a part of the plaster with which the sides of the window were covered, and which, having been more strongly acted upon by the light, than the bits of linen wetted with the same liquor in the interior part of the room, had become purple, though the day was then cloudy. Without, however, perceiving this to have been the cause of his disappointment, he broke off a bit of the same plaster, and carrying it to the back part of the room, where the bits of linen in question were laying, he wetted it with the same liquor, without its becoming coloured. He then thought of carrying the colourless bits of linen to the window, which was open, and there he soon perceived them to become purple. It was then fashionable to explain all effects upon mechanical principles, as it was at the time when he also endeavoured to account for the shock of the torpedo, as resulting *mechanically* from a very quick stroke given by the contraction of particular muscles in that fish. Mr. Reaumur, therefore, soon persuaded himself, and others, that the bits of linen which had remained colourless whilst at the back part of his room, were rendered purple at the window by the different manner in which the air acted upon the colouring liquor in the latter; and that this

difference consisted solely in the air's having greater motion at the window, than at a distance from it; and almost all his subsequent experiments seem to have been calculated to confirm this hypothesis.

He placed bits of linen, just wetted with the colouring liquor, in the open air, and laying a stone upon each, he found the covered part remain colourless, whilst the rest were made purple; which he ascribes to the mechanical impression of wind, not considering that the stones kept off the light, as well as the air. Having read an account of Mr. Cole's observations, in the Philosophical Transactions, Mr. Reaumur exposed a bit of linen, wetted with the colouring liquor, to the rays of the sun, collected by a small burning glass, and saw it become purple in an instant; and consequently, without being able to distinguish any of the changes of colour through which it had so rapidly passed. Putting another bit of linen, wetted with the same liquor, so near to the fire that it would have burned had it been dry, he likewise saw it become purple immediately; but with equal degrees of heat, the effects produced by the sun's rays were beyond comparison the greatest.

Mr. Reaumur conceived the grains in question to be the eggs or spawn of some fish, but whether of the buccinum, or any other species, he was uncertain; and under this uncertainty he proposed calling them "*Oeufs de Pourpre*," eggs of purple. The colour which they produced, was at least equal, if not superior in beauty, as well as durability, to that of the buccinum:

though

though the colouring liquor of the latter was much thicker than that of the purple eggs, and not liable to pass through the different changes of colour so quickly as that of the eggs, excepting when diluted. Having put some of this diluted liquor into two glasses, and placed one of them in contact with the sun's rays, and the other near the fire, the former became purple without any sensible addition of heat, whilst that which was at the fire had only began to acquire the first shade of colour though it was sensibly hot: and indeed he always found the colours produced by the sun to be more beautiful than any others; a circumstance which he endeavours to explain, by supposing its rays to act mechanically, in changing the figures or arrangements of the particles of the liquor, in the same way as he supposed the wind to change them, but with more efficacy. When Mr. Reaumur returned from the sea-coast to Paris, he filled two phials with the diluted liquor of the buccinum, which he brought with him, and upon examining them at the end of his journey, he found that one of them remained colourless as at first, it being full of the liquor; the other, however, having been ill corked, had lost an eighth part of its contents, and had, as he says, acquired a little colour; which he attributes to the mechanical effects of shaking from the phial imperfectly filled.

Mr. Reaumur perceived the same disagreeable smell of garlick from the liquor which Mr. Cole had before mentioned; and he found it the more insupportable, as the heat of the sun or fire was the strongest. The colour of the liquor was not

produced, or affected either by vegetable alkali (carbonate of pot-ash), or sulphuric acid: but a very little corrosive sublimate, put into the diluted liquor of the buccinum, instantly rendered it blue, and the colour was soon precipitated with the mercury, to the bottom of the vessel, leaving the liquor colourless; an effect which, as usual, he endeavoured to explain mechanically, by supposing the sublimate to consist of little globules, stuck round with sharp points, which enabled it to change the arrangement of the particles of the liquor more expeditiously, even than he had supposed it done by the wind. He found that the liquor of the buccinum tasted as hot as the hottest pepper, whilst that of the purple eggs was saltish; but even this was so viscid, that it did not run, when topically applied to linen, &c.; and as the eggs were, according to Mr. Reaumur's account, so plentiful¹, that one man might collect half a bushel of them in a few hours, there certainly is reason to think that they would be highly useful, at least in calico printing, where their liquor might be applied, with the greatest facility, both for penciling and printing, as a substantive topical colour, and where a small quantity would go far, especially upon fine muslins. But at that time the art of calico printing had never been practised in France, and therefore nobody thought of applying Mr. Reaumur's discovery to that purpose.

About the beginning of the year 1736, Mr. Duhamel found the purpura (the buccinum only

¹ See Mem. de l'Acad. Royale des Sciences, &c. an. 1711.

having

having been discovered by Cole and Reaumur) in great abundance upon the coast of Provence; and found it to agree very well with the description thereof given by Rondelet. He found the viscid colouring liquor of the fish to be white, except in a few instances, where it was green, which he suspected to be some morbid effect. The white liquor being exposed to the sun's rays, assumed the following colours: 1. a pale green and yellow; 2. an emerald green; 3. a dark bluish green; 4. a blue, with a beginning redness; and 5. a purple; and these all happened in less than five minutes. Linen wetted with the white liquor, and left all night in a dark room, had only become green in the morning; and this was also the case of linen wetted in like manner, and exposed all night in the open air, but shaded from the moon's light. A piece of linen, wetted in the same manner, being partly exposed to the sun's rays, and partly hid by a crown-piece of silver, the former became purple, whilst the latter was only green. Other linen so wetted, being heated in a Dutch oven before the fire, or on a hot iron, became of a dark green, but not purple. The fumes of burning sulphur only produced a dark green; and this was moreover the case with the different coloured rays of the sun, applied separately by a prism. Wishing to see whether evaporation tended to colour the white liquor, Mr. Duhamel put some of it into a phial well stopped; and, upon exposing it to the sun, found the liquor become of a reddish purple almost immediately. A piece of linen wetted, and stuck upon the back of a plate of polished glass, three lines in thickness, and exposed to the sun's rays, became purple even before

before it had dried. Three pieces of linen so wetted, being covered, one with white, a second with black, and the third with oiled paper, the last soon became a good purple colour, but the others only became green. Linens wetted in like manner, and exposed to the light of the moon, or of burning wood or candles, became green, but not purple. Exposure to the sun's rays always produced the purple, and most expeditiously, when its light and heat were strongest. The sun-shine of the month of March having proved much more efficacious than that of January or February, the purple was instantly produced by the sun's rays, collected under a burning glass. The liquor which Mr. Duhamel suspected to be morbidly green, became purple sooner than the white liquor; a circumstance which does not indicate its greenness to have been the effect of disease. In linens where the colour had stopped at the green, without reaching the purple hue, it was soon carried off by boiling with soap, fossil alkali, alum, &c. which the colours that had become purple withstood for a long time, and were not hurt by the fumes of burning sulphur. See *Memoirs of the Royal Academy of Sciences*, &c. 1736.

Until Mr. Cole had discovered the buccinum, no adequate conceptions could have been formed of the changes through which its liquor and that of the purpura became purple. Aristotle and Pliny had, indeed, both given intimations of their being primitively white; and Pliny had mentioned one of the intermediate colours, the green². That the other changes were not

² "Color austerus in Glaucis, & irascenti similis mari." *Lib. ix. sect. 60.*

more

more distinctly noticed, must be ascribed to the little attention then bestowed upon subjects of natural philosophy, and perhaps to a want of sufficient communication with the *purpurarii piscatores*, by whom the liquor was collected and salted. And there can be no doubt of the identity of the shell-fish employed by the ancients, and those discovered by Cole, Reaumur, and Duhamel, or of the similitude of changes and means by which their several liquors became purple. In a collection of *Anecdota Græca*, lately published by M. d'Anse de Villoison, there is, as Mr. Berthollet mentions, a description of the manner of catching the shell-fish, employed for the purple dye, written by an eye-witness, Eudocia Macrembolitissa, daughter of Constantine the eighth, who lived in the eleventh century, while the knowledge and practice of dying that colour for the use, and at the expence, of the Greek emperors still subsisted; and from which it manifestly appears, that in those times, as well as in ours, the purple did not acquire its due lustre and perfection until it had been exposed to the sun's rays.

Those who are duly acquainted with the more recent chymical discoveries, can only hesitate between two ways of accounting for the changes through which the liquors of the *purpura* and *buccinum* become purple; I mean, whether it be by gaining oxygene from the atmosphere, as happens when indigo acquires its blue colour; or whether it be not rather by the separation of a redundant portion of oxygene, naturally combined for some unknown, but necessary purpose in the liquor of these shell-fish; and in that particular

particular state which will not admit of its being separated without the application and assistance of light; as is also the case of horned silver, rendered purple by the sun's rays; of vegetables, rendered green by the same cause, after they had become white by growing in darkness; of peaches, purple grapes, and other fruit, which never acquire their proper colours by any degrees of heat, but always remain white or green if shaded and secluded from the contact of the sun's rays. A very few experiments which I hope to have an opportunity of making hereafter, would ascertain this point beyond the possibility of doubt; though in fact there is, I think, at present very little room to doubt but that the purple, under consideration, is produced in the last of the two ways just mentioned.

The celebrated Fontenelle, in giving his account of Reaumur's discovery of the purple, began by observing, that not only more things were found in modern than had been lost in ancient times, but that it was even impossible for any thing to be lost unless mankind were willing that it should remain so; it being only necessary to search in the bosom of nature where nothing is annihilated; and that to be certain of the possibility of a thing's being found, was a considerable step towards finding it. But before the buccinum and purpura were found by Cole, Reaumur, and Duhamel, America had been discovered, and new dying materials obtained from thence, superior in beauty, and especially in cheapness, to those so highly valued in ancient times, at least for wool; though it must be confessed that no other substance will afford a durable

durable substantive purple to linens or cottons, capable of being topically applied with so much simplicity and expedition; and for these reasons it seems probable that the discoveries of these Gentlemen might still be applied with advantage in staining or printing fine muslins, for which but little colouring is required. And indeed, there was a species of buccinum found about a century ago near Panama, and particularly on the coasts of Guayaquil and Guatemala, of which constant use appears to have been made in those countries for purposes of dying cotton. Jussieu the elder, Thomas Gage, and others, have mentioned them; Don Antonio Ulloa, in particular, says, "they are something larger than a nut, and contain a juice which, when expressed, is the true purple; for if a thread of cotton or the like be dipped into this liquor, it becomes of a most vivid colour, which repeated washings are so far from obliterating, that they rather improve it; nor does it fade by wearing." "This precious juice," continues he, "is extracted by different methods; some take the fish out of the shell, and laying in on the back of the hand press it with a knife from head to tail, separating that part of the body into which the compression has forced the juice, and throw away the rest." This being done, "they draw threads through the liquor which is the whole process; but the purple tinge does not appear immediately, the juice being at first of a milky colour, from which it changes to a green, and, lastly, to this celebrated purple."

Snails, with the same property, exist in various other parts of the world. Mr. John Nicuhoff relates

relates that "*abundance* of purple snails are found in the islands over against Batavia." "They are boiled (adds he) and eaten by the Chinese, who have a way of polishing the shells, and pick out of the middle of the snail a certain purple-coloured substance which they use in colouring and making red ink.

In the fiftieth volume of the Philosophical Transactions, Dr. J. A. Peyssonnel, F. R. S. then residing at Guadelupe, describes what he calls the naked snail producing purple, "*Limax non cochleata, purpur ferens*," as found in the seas of the Antilles, and "precious for the beautiful purple colour it produces in the same manner that the cuttle-fish produces its ink." "There is (continues he) a hollow in the back of the animal where the canal, filled with a reddish juice, passes out carrying it to a fringed body like a mesentery; and it is there the purple juice is brought to perfection." "When the animal is touched, he makes himself round and throws out his purple juice as the cuttle-fish does his ink: this juice is of a beautiful deep colour; it tinges linen, and the tincture is difficult to get out."

It is however to be remarked, that the liquor of the naked snail exists naturally of a purple colour, without the application of light; a circumstance which denotes very different properties. In Brown's History of Jamaica, there are descriptions of two shell-fishes having a similar colouring liquor; one is termed "the larger dark *lérnea*, or sea-snail, frequent in the American seas." Dr. Brown observes, that "on touch-
ing

ing this creature, it emits a considerable quantity of viscid purple liquor, which thickens and colours water about it so much that it can scarcely be seen for some time after, by which means it is generally enabled to make its escape in times of danger." "I have gathered," adds Dr. Brown, "a small quantity of the discharges of this creature, and stained a linen handkerchief with it; it gives a very beautiful dark purple colour which is not apt to change with either acids or alkalies; but is easily washed out:" a circumstance in which it totally differs from the buccinum, &c. as well as in that of liquor being naturally emitted of a purple colour. The other of these shell-fish is termed the purple ocean shell, and upon being touched, "it discharges a beautiful purple liquor," says Dr. Brown, which seems to resemble the former. The sepia, or cuttle-fish, has long been known to provide for its safety in like manner, by discharging in times of danger a viscid bitter black fluid, which Rondolet seems with reason to have considered as its bile. It was used as ink by the Romans; and is said at this time to form the basis of Chinese ink. I suspect however, that neither this, nor the liquor of either Dr. Brown's shell-fishes, or of Dr. Peyssonnel's naked snail, possess such properties in dying, as to merit the denomination of substantive colours.

Being at sea in the year 1783, on my passage from London to Philadelphia, I caught the *boluthuria physalis* of Linneus, called the man of war, or Portuguese man of war, by English seamen. Some of them are of a beautiful crimson, though this was of a fine purple colour,

and when cut open, yielded a fluid of the same colour; with some of which I stained the corner of a cambrick handkerchief, which was afterwards washed in its turn, with about two dozen more, during nine months which I passed in America, without having, as far as I can remember, lost much of its colour; but soon after, upon my return to London, it was picked out of my pocket, before I was able thoroughly to ascertain how far the very acid liquor of the *holothuria physalis* would yield a permanent substantive dye.

There are several other animal matters which seem worthy of being tried for dying, and particularly a large green worm, infesting the tobacco plants in North America, and which, upon being bruised, yields a considerable portion of green liquor, which indeed I have not had an opportunity of trying, since the idea of its probable utility in this way occurred to my mind.

Mr. Martin Lister (see Philosophical Transactions, vol. vi.) observes, that "the common hawthorn caterpillar will strike a purple, or carnation, with lye, and stand; the heads of beetles and pismires will, with lye, strike the same carnation colour, and stand; and the amber-coloured scolopendra (adds he) will give, with lye, a most beautiful and pleasant amethystine, and stand:" but whether he means that they will stand in this way, when applied to paper only, or to the substances usually made to receive dyes, does not appear. In another part of the same volume, Mr. Lister mentions an insect (*cimex*), whose

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whose eggs, bruised upon white paper, "stain it of themselves, without any addition of salt, of a lively vermilion colour."

C H A P. V.

Of Vegetable Substantive Colours.

"Combien de tentatives n'aura t'on pas fait avant que
"de parvenir au point d'appliquer convenablement
"les couleurs sur les étoffes, et de leur donner
"cette adherence et ce lustre qui fait le principal
"merite de l'art du teinturier, un des plus agre-
"ables, mais en meme temps un des plus difficiles
"qu'on connoisse!" GOUBET *de l'Origine des*
Lois, des Arts, et des Sciences, &c. tome premier, 4to.

INDIGO is probably the most ancient of all vegetable colouring matters within our knowledge, though not used for dying in Europe until near the middle of the sixteenth century. Pliny mentions a substance brought from India, and termed Indicum, which was doubtless indigo; though he appears to have had but very inaccurate ideas of it, and to have considered it as the scum, or exudation of certain reeds adhering to mud: "ab hoc maxima auctoritas Indico, ex India venit arundinem spumæ adhærescente limo; cum teritur nigrum, at in diluendo mixturam purpuræ cæruleique mirabilem reddit." Plinii, l. xxxv. c. vi. Dioscorides thought it a stone.

We have no reason to believe, that either the Greeks or Romans ever knew how to dissolve indigo, or use it for dying, or any purpose but
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that of painting; though it undoubtedly was used long before, as a dye in Hindostan. The first indigo employed in this way by Europeans, was brought by the Dutch from India. A species of the plant, from which it is there extracted, was soon after recognized, and made use of for that purpose, by the Portuguese in Brazil, where it grew spontaneously, as it also did in other parts of America. Clavigero, in his History of Mexico, mentions indigo as having been prepared, and used by the Mexicans, before the Spaniards arrived in that country; and he gives an account (superficial indeed) of the process for obtaining it. Hernandez had long before described the indigo plant as being indigenous in Mexico, and employed by its ancient inhabitants; and Ferdinand Columbus, in his Life of Christopher Columbus, mentions it as one of the native plants of Hispaniola. Though the Abbé Raynal asserts, that it was transplanted from the East Indies to America; which can only be true of one of the species, the *indigofera tinctoria* Linn.

There are various species of the *indigofera*, or indigo plant, growing in China, Hindostan, Japan, Java, and Madagascar, as well as in America, and differing considerably from each other; though their several peculiarities have not been well ascertained. Three species only of this genus are cultivated in America. The first, and smallest, is the *indigofera tinctoria* of Linnaeus, which is neither so hardy, nor is its pulp so good, as that of the others; though it yields much more, and is therefore generally preferred to both. This is what the French call *indigo-franc*.

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franc. The second is the *indigofera disperma* Linn. or Guatimala indigo plant, which grows much higher, is hardier, and affords a better pulp than the former. The third is the *indigofera argentea*, or wild indigo, called indigo bâtard by the French, which is hardier than either of the others, and yields the finest pulp, though the least in quantity.

The indigo plant being cut at maturity, by rape hooks, a few inches above the ground, is laid by strata in a steeper, then overlaid with boards, and covered with water; in which it is left to digest and ferment until the pulp is extracted. To ascertain when this is done, or when the fermentation has risen sufficiently high, and continued a sufficient time, handfuls of the plant are drawn out every five minutes; and as soon as the tops become both tender and pale, and the stronger leaves, without being tender, are found to be pale, the liquor is drawn off immediately into the beaters: doing this too soon would occasion the loss of a great part of the pulp; and suffering the liquor to ferment too long, would spoil the whole.

When the liquor is all discharged into the beaters, it is agitated with buckets, or by suitable machines, until the tincture begins to granulate, or collect into little floculæ; and to hasten this kind of granulation, or separation, it has long been usual to add clear lime water, in greater or smaller quantities, until the liquor, in which the *blue* floculæ are suspended, becomes, in other respects, colourless. Great attention and exactness are necessary in this, as well as in

the former process, to render the quality of the indigo perfect; it is moreover requisite that the lime water employed should be perfectly clear, otherwise it will render the indigo hard, heavy, and of a greyish cast.

The liquor having been sufficiently agitated, and impregnated with lime water, is left at rest, that the particles of the indigo may quietly fall to the bottom; and this being done, the clear water is drawn off by a tap, placed just above the top of the feculence or magma, which is afterwards discharged, by an opening below, into another receptacle, and from thence conveyed into linen bags, which are suspended in order to let the water drain off; and this being done, the indigo is put into little square boxes, or formed by hands, into small lumps of different sizes and figures, and afterwards dried in the shade.

Indigo seems to consist chiefly of a particular vegetable basis, united to a large portion of oxygene, to which its colour is principally owing, and for which it has a strong attraction. In the first operation, that of steeping and fermenting the plant, this basis is not only dissolved and extracted by the water, but a portion of pure air is absorbed (as is the case in all similar fermentations), some of which combines with the basis of indigo, which would indeed absorb so much as to become black by a kind of combustion, if the fermentation were not previously stopped. In the second operation, by beating and agitating the liquor, a farther addition is made of oxygene, accompanied with a proportionate change of colour, through the several shades

shades of green progressively to those of blue; and also a collection of the very minute coloured particles into little distinct masses, or floculæ. This is somewhat analogous to the effects of churning on cream, or of violent shaking upon ink in a bottle, by which its colouring matter soon forms large granulations, and falls to the bottom, where it continues incapable of being ever afterwards re-dissolved, or suspended by the water, which it leaves perfectly clear. The addition of lime water farther promotes the separation of the blue particles, by absorbing the carbonic acid produced by the previous fermentation of the liquor, and still contained in it.

At that precise state when the indigo is of a full deep green, and before any perceptible separation or collection of its coloured particles has taken place, it is, I am persuaded, in the state the best suited of all others to dye the most permanent, if not the most lively colours. The remaining parts of the process serve only to collect the substance of the indigo into a dry solid form, in which it may be more conveniently preserved, and transported to distant countries for after use.

I have mentioned that too much fermentation, during the first part of the process, would produce a beginning of combustion, and blackness in the pulp of the indigo; and the like effects result from too much beating, or agitation in the second. On the other hand, if the coloured particles were separated by lime water, before they had acquired a sufficiency of oxygene by agitation, the indigo would have a greenish

cast, which is carefully avoided, as it might seem an unfavourable circumstance to persons unacquainted with the true cause; though I am inclined to believe that such indigo would, in some respects, be preferable to the other, especially as it would be more easily brought into the state of solution necessary for dying.

Indigo differs considerably in colour; though its differences in this respect may be comprehended under three general divisions; the blue, the violet, and the copper-coloured; and each of these is the more pure and valuable, in proportion as it is more light: the lightest indigo is always blue, and sells for the highest price; this is more especially employed for dying Saxon blue. It is not yet known (though it has long been a desideratum) how either the blue, the purple, or the copper-coloured indigo may always be certainly produced, at the option of the operator. I shall hereafter offer some conjectures on this circumstance.

Of American indigo, that of Guatimala is the most esteemed; but of this there are three sorts, the copper, violet, and blue; the last and best is termed *Flora* by the Spaniards, and it floats on water. The indigo of Java was formerly most esteemed in the East Indies; but the culture of the indigo plant having of late been greatly encouraged within the English East India Company's possessions, indigo, superior even to that of Guatimala, is now brought from thence in considerable quantities. The whole quantity imported annually into Great Britain, considerably exceeds one million of pounds weight.

weight. One English acre of rich land, by proper cultivation and management, may be made to yield five hundred pounds of indigo annually. The lightest and best indigo burns almost wholly away, leaving but a very small portion of white ashes behind.

The same colours, and shades of colour, may be given by all the different kinds of indigo; which seem therefore to differ principally by containing more or fewer impurities, and consequently more or less colouring matter. Water dissolves the mucilaginous, and some of the adventitious parts of indigo; of which alkohol dissolves others; but neither can dissolve any part of its colouring matter; and this is also true of all the alkalies, whether caustic or aerated, and of all acids, the nitric and sulphuric excepted. There are, indeed, but two ways in which indigo, when once formed, can be dissolved: the first of these is by means which attack its basis, by superadding a farther portion of oxygene; the other is by substances which absorb and take away from indigo a considerable part of the oxygene combined with it, so as thereby to render its basis liable to be acted upon, and dissolved by the pure or caustic alkalies.

In the first of these ways, fire speedily decomposes indigo: the nitric acid also, when concentrated, attacks it so powerfully, as to produce actual ignition; and even when diluted it not only destroys the blue colour immediately, but dissipates the greatest part of its substance, in the form of vapour, by a slower combustion, leaving

behind a rusty iron-coloured gummo-resinous mass, soluble in alcohol, and partly so in water, but of no use.

Indigo reduced to powder, and mixed with five or six times its weight of strong sulphuric acid (oil of vitriol), will be attacked with considerable activity and heat; and in about twenty-four hours it will be dissolved. When acted upon by this acid, the colour of the indigo is rendered more lively and beautiful by the addition of a farther portion of oxygen, though it becomes less durable, because the basis is made weaker by the action and further addition of oxygen; but more of this when treating of the Saxon blue.

The muriatic acid, in its most concentrated state, has no sensible action upon the pure colouring matter of indigo, though it dissolves some other parts of it. By an equal mixture of nitric and muriatic acids, indigo was rapidly dissolved, and its colour destroyed, nearly in the same way as by the nitric acid only.

Having produced a mixture of vitriolic and muriatic acids, by pouring a sufficient quantity of oil of vitriol upon sea salt, I found it dissolve the indigo more slowly indeed than the sulphuric acid alone; but the solution seemed to answer equally well for the purposes of dying. It must be observed, however, that neither the sulphuric, nor even the nitrous acid, when greatly diluted, are capable of dissolving the colouring matter of indigo.

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The oxygenated muriatic acid acts but very feebly upon indigo, whilst in substance; but when dissolved it destroys the colour. Mr. Berthollet availed himself of this circumstance, to obtain a measure for ascertaining the proportionate quantity of colouring matter in different kinds of indigo, by finding how much of the muriatic acid was necessary to destroy the colour of a given quantity of indigo, previously dissolved by sulphuric acid. I think, however, this might be done with certainty, by seeing how much wool a given quantity, so dissolved, would dye of a particular shade. I have found, that, by adding a little manganese to the solution of indigo, by oil of vitriol, the blue colour was destroyed as efficaciously, and in the same way, as by oxygenated muriatic acid.

The tartarous, acetous, phosphoric, fluoric, and other acids, seem to have no action on the colouring matter of indigo.

None of the alkalies, either pot-ash, soda, or ammoniac, whether mild or caustic, have any action upon the colouring matter of indigo, unless when it has been previously dissolved by vitriolic acid, or deprived of a portion of oxygen, as will be hereafter explained; nor has lime water any power of dissolving it.

In the second, and only way of dissolving indigo, without lessening the durability of its colour, there is no one substance, or agent in nature, capable of producing this effect; but it results from the concurrent action of different agents.

Previous

Previous to the use of indigo in Europe, the blue dye was obtained solely from the *isatis* (*glastum*), or woad, of which there are two species; the *isatis tinctoria* (commonly cultivated in this kingdom), and the *isatis lusitannica* Linn. of which the last is somewhat smaller than the first. This plant being cut down at maturity, washed, and then expeditiously dried in the sun, is afterwards ground in a mill, then placed in heaps, secured (by being covered) from the rain, and left to ferment during fourteen or fifteen days; the external and internal parts are then well mixed together by stirring, and the whole is formed into balls, piled upon each other, and exposed to wind and sun, in order that the remaining humidity may evaporate: but while this is doing, the balls begin again gradually to ferment, become hot, and exhale a portion of ammoniac, or volatile alkali; and if necessary, the heat and fermentation are promoted, by occasionally wetting the mass until it assumes the form in which it is commonly offered for sale. The proper modes of conducting the fermentation, and the exact times at which it ought to be stopped, still remain so uncertain, that those who make it their business to prepare woad, have no certain facts or indications to govern their management in these respects; and the goodness of any particular quantity, or mass, can never be ascertained otherwise than by the actual use which the dyer makes of it. The article is therefore bought and sold under the greatest uncertainties respecting its true value and fitness to answer the purposes for which it is intended.

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The isatis contains the basis of a blue colour, very similar to that of indigo; but, by the process just described, this basis receives the changes which arise from fermentation, without being extracted from the plant, and collected, like indigo, into distinct masses. Astruc, however, some years ago, maintained the practicability of obtaining indigo from the isatis; and this has been lately done in Germany, by a process so nearly resembling that employed for producing indigo, as not to merit a particular description. Mr. d'Ambourney has also done the same thing lately at Rouen, in small quantities. But it seems probable, that, except for ascertaining the practicability of doing this, no benefit will ever result from it, since the indigo may doubtless be produced in, and imported from, other countries, with much less expence than it will cost when obtained in Europe from woad. Mr. d'Ambourney mentions the "*lymbe violet*," or violet border, as a sign of the maturity of the pastel or woad; that in fermenting it with water to make indigo, the liquor on the third day appeared *green*, but the surface was covered with a kind of *blue* powder: that on the fourth day the leaves of woad seeming sufficiently macerated, and exhaling an acidofœtid odour, were taken out, and the remaining liquor appeared of an olive colour: that on the fifth day, finding in it no disposition to a separation, and subsidence of colouring matter, he put into it a portion of caustic soap lees, and beat it with rods to promote this precipitation; after which the olive colour became of a duck green, then of a slate-coloured blue, with a bluish froth. Mr. d'Ambourney found, in fermenting the leaves of
pastel,

pastel, that the addition of an alkali, before the green colour was formed, wholly prevented it, and that a putrid fermentation took place in its stead. He concludes, that one hundred pounds of the leaves may yield about one pound and a half of indigo.

Woad alone dyes a blue colour very durable, but less vivid and beautiful than that of indigo; it is therefore, at present, never used except with indigo, in what is called the woad-vat, in which it is made to ferment with water, by a suitable degree of warmth, and the addition of bran, with other vegetable matters: to these, indigo and lime are afterwards joined; and the indigo being deprived of a portion of its oxygene by the fermenting vegetable substances, is thereby rendered soluble by the lime; and being in this way soon combined with the colouring matter of the woad, both form a dying liquor, blue or copper-coloured on the surface, where it can re-absorb the oxygenous gas, but green immediately beneath the surface, and throughout the whole mass. When the liquor becomes, and while it continues, green, it is fit for dying; and cloth or wool dyed with it, though they appear green when taken out, become blue immediately, by attracting and combining with the oxygene; the loss of which had previously rendered the liquor of the woad-vat green. The use of indigo had scarcely been introduced into Europe, before it was prohibited in some countries, from a persuasion that its colour was fugitive; and in France, under the enlightened administration of Colbert, the use of it was only permitted in a certain small proportion, along with woad,

woad, in forming the vat just mentioned; so very liable are mankind to entertain false opinions respecting the value and properties of dying drugs.

There are various other blue vats in which indigo is dissolved, and made fit for dying, without being united to woad. These, however, are generally known, and have, moreover, been sufficiently described by Hellor, Quatremere, Le Pileur d'Apligny, Berthollet, and others. They differ considerably from each other; but in all of them the indigo is first deprived of a portion of its oxygene, by the attraction of vegetable or animal ferments, or of the oxyd of iron (separated from copperas); and then it is dissolved either by lime, or by some alkali, either vegetable, mineral, or volatile. The woad-vat first mentioned is almost the only one used for dying wool, and woollen cloths or stuffs. Silk is commonly dyed from a different vat, in which indigo (without any woad) by the aid of a sufficient degree of warmth and of vegetable alkali, with vegetable ferments, bran and madder, is dissolved, and made to produce a fine green liquor, with a bluish copper-coloured scum on the surface, &c. Indigo, however, is incapable of dying silk of a *deep* blue colour, without the help of archil, or some other colouring matter.

Cotton is dyed in a blue vat, into which indigo, ground either in water, or in a caustic alkaline ley, is put, with two or three times its weight of lime, previously slacked in a sufficient quantity of water, and about one-fourth less of
copperas

copperas (sulphat of iron) than of lime. When this mixture is made, a part of the lime unites with the acid of the copperas, forming calcareous sulphat or selenite, and at the same time precipitates the oxyd of iron, which, not being saturated with oxygene, attracts so much of that which was combined with the indigo, as to render this last substance soluble, by the lime remaining over and above what was employed to saturate the sulphuric acid. The beginning dissolution of the indigo may be perceived by a shining copper-coloured pellicle, which forms itself on the surface of the mixture, while the liquor itself becomes green, and afterwards gradually inclines more and more to the yellow, as the solution advances. When it is completed, and the liquor settled, the cotton, yarn, or stuffs are to be dyed in it: at first they will appear yellow when taken out, but by absorbing the oxygene, they rapidly assume and pass through the different shades of green, and in a few minutes become blue, the oxygene regenerating the indigo in the pores of the cotton. Mr. Haussman, of Colmar in Alsace, who, with a good stock of chymical knowledge, daily practises the arts of dying and callico printing, lately published an excellent "Memoire sur l'Indigo & ses dissolvans," in the Journal de Physique, &c. for March 1788, in which he mentions, that the change of colour from yellow to blue, in cottons dyed as before mentioned, may be greatly accelerated, and their colours made deeper than they would otherwise become by plunging the dyed cottons, when first taken out of the vat, into water soured by vitriolic acid, which hastens the regeneration of the indigo,

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and moreover dissolves and carries off a portion of white calcareous sulphat or selenite, which would weaken the strength or intensity of the blue colour.

If the colour of the vat be not all used soon after it has been prepared, it will require occasional stirring; since the dissolved indigo, by continually absorbing oxygenous gas from the atmosphere, will be constantly reviving, in considerable quantities, upon the surface of the liquor; and the indigo so revived can only be redissolved by being again subjected to the combined action of lime, and oxyd of iron: if by length of time these should become perfectly saturated with oxygene and carbonic acid, before the blue colour is all used, a farther portion of each must be added, and somewhat more of lime than of copperas.

Mr. Hauffman observes, that all the precipitates of iron, whether obtained from solutions of that metal by the mineral, vegetable, or animal acids, will serve, with quick lime, to dissolve indigo, as well as that of green vitriol, provided, or so long as they retain the property of absorbing vital air; but that a nitric solution of iron, or the rust of it, or any other preparation where it exists in an ochrous form, not attracted by the magnet, nor capable of attracting pure air, will be wholly useless towards producing a dissolution of indigo, though employed with an excess of quick lime, or of caustic alkali. He conceives, that the precipitate of iron, obtained from copperas, promotes the dissolution of indigo by its phlogiston; and that he cannot satisfactorily explain

plain this effect upon the new system, unless by supposing, that the oxygene only adheres to the integrant molecules of the indigo, without an actual combination (which he thinks improbable); and that the oxygene having stronger affinity to the precipitate of iron than to the indigo, quits the latter to unite with the former; while the indigo, in giving up the oxygene, unites with the lime, or caustic alkali, and is dissolved by them; which indeed seems to be the true explanation.

Mr. Hauffman further observes, that caustic alkali, with fine iron filings, instead of the precipitate from copperas, would not dissolve indigo; but that (regulus of) antimony, brought into the form of a powder, dissolved it perfectly with the caustic alkali, or quick lime slacked by water; though the calces, or oxyds of antimony, in this way, produced no such effect: nor did any precipitates of copper: on the contrary, they all seemed rather to hasten the regeneration of indigo, after it had been dissolved by some other means: and he adds, that some dyers avail themselves of this effect, to obtain, at once, all the colour remaining in a blue vat (after it has been too weak to dye properly), by passing cottons through water in which a little sulphat of copper (blue vitriol) has been dissolved, and then dying them in the vat intended to be exhausted, where the solution of copper speedily precipitates, and revives the remaining indigo in the pores of the cotton.

I have repeated most of Mr. Hauffman's experiments, with different precipitates, or oxyds

of iron, and with effects nearly similar to those he describes. I found that neither the rust of iron, nor the nitric oxyd of it, would assist in the dissolution of indigo; obviously because they were both already saturated with oxygene: I also found, that even a precipitate of copperas failed for the same reason, when, instead of separating it by lime, it was made by dissolving copperas in water, and leaving it for some weeks exposed to the air in warm weather, where the iron was farther acted upon, and saturated, as well as precipitated, by the oxygene which it gained from the atmosphere.

It is nearly in the same way, and upon the same principle, that the topical indigo blue, employed by calico printers for penciling, is made: the ingredients of this composition are employed in different proportions in different places; and will succeed with very considerable latitude in this respect: indeed, the different qualities of indigo necessarily render it impossible to prescribe any exact proportions, which shall be always equally efficacious and suitable.

Mr. Hauffman mixes twenty-five gallons of water with sixteen pounds of indigo, well ground (or a greater or smaller quantity, according to the quality of the indigo, and the depth of colour wanted), to which he adds thirty pounds of good carbonate of pot-ash, placing the whole over a fire; and as soon as the mixture begins to boil, he adds, by a little at a time, twelve pounds of quick lime, to render the alkali caustic, by absorbing its carbonic acid, or fixed air. This being done, twelve pounds of red orpiment

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are also added to the mixture, which is then stirred, and left to boil for some little time, that the indigo may be perfectly dissolved; which may be known by its giving a yellow colour, immediately upon being applied to a piece of white transparent glass. M. Oberkamp, proprietor of the celebrated manufactory at Jouy near Versailles, uses a third more of indigo; and others use different proportions, not only of indigo, but of lime, pot-ash, and orpiment; which all seem to answer with nearly equal success: but with the best copper-coloured Guatamala indigo, it is certain that a good blue may be obtained from only half the quantity prescribed by Mr. Hauffman, by using as much stone, or oyster-shell lime, as of indigo, nearly twice as much pot-ash, and a fourth part less of orpiment than of indigo. This composition is greatly defended from air by gum, which should be dissolved in it whilst hot; and it should afterwards be kept secluded as much as possible from the contact both of vital air, and carbonic acid gas or fixed air.

Indigo dissolved in this way, for penciling or printing, I shall hereafter call *topical blue*—its strong tendency to attract oxygene from the atmosphere, and to be thereby regenerated, renders its use subject to many difficulties; it being almost impossible to pencil, and more so to print, a piece of cotton throughout of the same shade, with the best endeavours, to apply it equally, and quickly, by the most expert and careful hands. It will give a fast colour only so long as it continues yellow, or, at most, of a yellowish green; as soon as it appears blue, the indigo
may

may be considered as revived, and incapable of fixing on the cotton: in this case, however, it may be re-dissolved, by adding more caustic alkali and orpiment. The clear liquor only, when gummed, is to be used; but it is not to be separated from the sediment, which helps to preserve it in a state of dissolution.

In making the before-mentioned composition, a copper-coloured pellicle appears on the surface of the liquor as soon as the indigo begins to dissolve; and this pellicle becomes violet, and at last blue, by longer exposure to the atmosphere. Mr. Haussman observes, that the same pellicle arises, with the same appearances, if the solution of indigo be put into contact with either the dephlogisticated or the vital airs; but that, under the receiver of a pneumatic machine, it diminishes in proportion as a vacuum is produced; and that it does not appear at all in the inflammable or the phlogisticated airs. Mr. Haussman farther observes, that if, instead of orpiment, sulphur and white arsenic, of which it is formed, be employed, either together or separately, with quick lime and pot-ash, no solution of indigo will take place; and this will also be the case, even where orpiment is used, if quick lime be not employed to render the alkali caustic. That having put indigo, dissolved by orpiment, lime, and pot-ash, into contact with dephlogisticated air (oxygenous gas), obtained by distillation from nitre, he found in a little time that seven-eighths of it were absorbed by the solution of indigo, and the remaining eighth was azote only (phlogisticated air); and the blue was rendered unfit for use, the indigo being re-

generated, as he found it; at other times, from the application of fixed air (carbonic acid); but with this difference, that a part of the alkali remained caustic, while another part of it combined with the vitriolic (sulphuric) acid (formed by the union of the sulphur to a part of the absorbed oxygene), and thereby produced vitriolated tartar (sulphat of pot-ash): another part of the oxygene, so absorbed, had combined with the arsenic, and changed its metallic form to that of an oxyd, in which state it had united to the caustic alkali; and the rest of the absorbed oxygene had combined with, and regenerated the dissolved indigo.

Mr. Hauffman was indeed inclined to explain the solution of indigo, according to the phlogistic system; by considering it as resulting from a greater affinity which phlogiston was supposed to have with indigo than with arsenic, and that it was the action of this phlogiston, joined to that of the caustic alkali, which operated the dissolution in question; but that the phlogiston, having still a greater affinity with dephlogisticated air than with indigo, abandoned the latter as soon as the former was presented to it, leaving the indigo in its regenerated form, the alkali alone not being sufficient to preserve it in a state of solution. But a much happier, and more natural explanation of these effects, is afforded by the new doctrine, as already stated; and it is strongly supported by all that we know of the nature of indigo, and the properties of those agents employed to dissolve it. Experiments made by Dr. Priestley, and others, evidently prove that iron, in the state in which it exists in copperas,

copperas, or when recently precipitated from a solution of copperas, forcibly attracts, and combines with, vital air brought into contact with it; and it is also well known, that the sulphuret of arsenic (orpiment) does the same, when dissolved by an alkali.

Mr. Hauffman found, that the sulphuret of antimony (crude antimony) assisted in dissolving the indigo, for topical blue, as well as orpiment, but that it was unfit for penciling or printing; because the antimony was precipitated, in the form of a mineral kermes or golden sulphur, tarnishing the blue colour, and adhering to the linens or cottons almost as strongly as the indigo itself. The oxyd of antimony, with sulphur, did not produce a solution of the indigo, when used instead of the crude antimony; though antimony, in its metallic state (*i. e.* the regulus), reduced to powder, had occasioned the dissolution of indigo in the same way, and as well as the crude antimony. He found, what is very remarkable, that no such effect was produced by the filings of zinc; though when heated it has great affinity with oxygene. He attempted, in vain, to dissolve indigo, by a combination of sulphur with the other metals (besides antimony and arsenic); and he attributes his want of success to the circumstance of their being dissolved with difficulty, or perhaps not at all “*par la voie humide,*” in the caustic alkalies.

Besides repeating a great part of these experiments, and with similar effects, I have made some, which, probably, were not attempted

before ; and several of them with effects highly deserving of notice.

I boiled, for two hours, the finest blue Guatamala indigo in water, with about four times its weight of highly-burnt oyster-shell lime, which I took hot from the fire, and put into the water, to see whether lime had, in this way, any action upon indigo : the better to ascertain this, I put into the boiling liquor a small piece of white broad cloth, and another of white calico : in about an hour both were taken out, and the broad cloth was so far dissolved by the lime, that it crumbled on being pressed between my fingers ; but the calico did not seem hurt ; though neither were in any degree coloured by the indigo. I afterwards added a quantity of pure carbonated pot-ash, equal to that of the lime which had been used ; and I continued the boiling for two hours more, and then leaving the liquor quiet, I soon found the indigo and lime had settled to the bottom, and left the water perfectly colourless. The next day the mixture was well stirred, and boiled again for two hours ; and being left to settle, it again gave the same proof of there having been no dissolution of the indigo. I had at hand about a pound of an oxyd of tin, prepared some time before (for a different purpose), by putting two pounds of common single aqua fortis, diluted with as much water, upon a quantity of tin, not in very small pieces, and leaving the former to act slowly upon the latter during several months, until all its oxygene was exhausted ; after which I found the oxyd, or calx, formed into lumps as large as a walnut, and

and settled at the bottom. The clear liquor being decanted from the oxyd of tin, the latter was slightly rinsed with water, and being dried, remained in solid lumps. Some of these, weighing about twice as much as the indigo which I had employed, were then put into the caustic alkaline liquor, in which I had ineffectually endeavoured to dissolve the indigo; and in less than five minutes I perceived signs of a beginning dissolution, which increased rapidly; and in half an hour the liquor had passed through all the shades of green, and become yellow, except at its surface, which was covered by a fine copper-coloured pellicle, of a shining metallic appearance. Silk and cotton dipped into the liquor, were taken out yellow, and became green, then assumed a shining copper-colour, and afterwards changed to violet, and then became blue; and were found, by washing, to be permanently dyed. Part of the same liquor, gummed, and applied topically, answered as well for penciling as any topical blue I ever saw. Another part of it, being poured into a white glass phial, so as to fill it to the top, with a portion of the lime and oxyd of tin, shaken all together, but without gum, and being well stopp'd and left at rest, in a few days became as pellucid and colourless as clean water, excepting only the sediment at bottom. Upon unstopping the phial, the surface of the liquor, coming into contact with the atmosphere, and absorbing oxygen, instantly became green and blue; and upon re-stopping the phial, and shaking it, the indigo forming this blue surface was dispersed through the mass of liquor, and tinged it of a beautiful greenish yellow; but there being a

sufficient quantity of oxyd of tin unsaturated, the oxygene was soon absorbed, and the liquor again rendered colourless: when, instead of the oxyd of tin, I employed the metal finely granulated, it produced no effect towards dissolving indigo; and on trying tin, which had been calcined with saltpetre in a crucible, I found that it not only did not dissolve the indigo itself, but prevented it from being dissolved by the oxyd of tin (produced by the aqua fortis, as just mentioned), or by crude antimony, or copperas either singly or combined; indeed it was with difficulty dissolved, when orpiment, in a large proportion, was added to all the above; this I also found to be the case of tin, calcined alone in a crucible by strong heat: bismuth calcined in like manner, equally obstructed the solution of indigo. Probably in these cases the metals so calcined not only do not attract the oxygene of indigo, but let go that which they had imbibed during calcination,

In the course of my experiments upon indigo, I was induced to make trial of refined sugar, instead of orpiment; and I found that the sugar acted very efficaciously in dissolving indigo, with the usual appearances, and producing a topical substantive blue, as permanent, and every way as good as any in use. I afterwards tried coarse brown sugar, and I found it at least as effectual as the refined, for this purpose; it then occurred to me, that this might be a valuable substitute for orpiment, the use of which, as a constituent part of the topical blue, may, from its poisonous quality, sometimes produce mischief, and always gives the composition an unpleasant

unpleasant smell. I moreover conceived, that, by employing a large proportion of brown sugar, it might be practicable to thicken the mixture sufficiently for penciling or printing, and thereby avoid the greater expence of gum for that purpose; and upon trial, this also proved to be the case, the sugar thickening the solution sufficiently, and afterwards drying as expeditiously as when thickened by gum, contrary to what I had apprehended as probable, from recollecting that ink, when thickened by sugar, was disposed to retain moisture, and dry very slowly. I think, moreover, that when the solution of indigo is both made and thickened by sugar, in this large proportion, the latter, by being able to absorb a larger quantity of oxygene from time to time, enables the topical blue to bear exposure to the atmosphere somewhat longer, without a regeneration of the indigo, than when it is dissolved by only the usual proportion of orpiment. I think, therefore, that this way of composing a substantive topical blue, by employing coarse brown sugar, instead of both orpiment and gum, is deserving of particular attention, as forming a composition free from all poisonous qualities, and at the same time cheaper and better than that generally used. Melasses will serve as well as brown sugar to promote the dissolution of indigo; but I think not so well to supply the place of gum in thickening the composition.

Sugar used in this way, seems to act like orpiment in combining with oxygene; which it is strongly disposed to do in other circumstances. M. Berthollet, in the second volume of the *Annales*

nales de Chymie, mentions, that, in distilling the sulphuric acid upon different animal and vegetable substances, he found none of them so proper to form a large quantity of sulphureous acid; which it could only produce by its great affinity with oxygene.

I found, upon different trials, that, with the help of pot-ash and lime, I could not dissolve indigo, either by sulphur, or white arsenic, or charcoal, or oxyd of bismuth, or of lead (minium), or of zinc (lapis calaminaris), or of manganese, or the alkaline solution of flints, or of the earth of alum, or by magnesia. I was equally unsuccessful with copper, as well in its metallic form, as in all the usual preparations of it: and indeed when indigo was mixed with verdigrise, lime, and pot-ash, as usual, it not only did not dissolve it, but the verdigrise prevented the action of all other agents upon it, in so much that the indigo remained undissolved, notwithstanding the combined action of crude antimony, orpiment, oxyd of tin, copperas, and sugar in large doses, any one of which, with the quick lime and pot-ash, would have effectually dissolved the indigo, had there been no verdigrise or copper in contact with it. The sulphat of zinc (white vitriol) was almost as adverse to the dissolution of indigo; for it not only did not contribute thereto, with pot-ash and lime, but it prevented any solution from taking place by the oxyd of tin, crude antimony, sugar, and copperas, applied one after the other: though when to all these a large portion of orpiment was added, and the mixture kept some time in a boiling heat, the indigo did at length dissolve, but

but with great difficulty and tardiness. Vermilion I found, on repeated trials, incapable of contributing, in any degree, to dissolve indigo with lime and pot-ash; though it did not obstruct the dissolution thereof, when orpiment was added. Camphor appeared to have no effect.

The topical blue, when made, is often applied by the pencil upon spots or figures previously dyed yellow, in order to produce a permanent green; but the caustic alkali contained in it, especially when employed too freely, seems to weaken the yellow on which it is laid. Wishing to remove this difficulty, I thought of neutralizing the alkali, at least in some degree, so as to make it harmless in this respect, without, at the same time, rendering the blue less efficacious. I could not, however, expect to do this, with either the nitric, sulphuric, or acetous acids; because they are now universally allowed to derive their acidity from oxygene; which, if applied to indigo, necessarily would produce the regeneration of it, and make it unfit for penciling or printing. I knew, however, that though Mr. Lavoisier had, from analogy, been induced to conclude that the muriatic acid derived its acidity, like most others, from oxygene, yet there was good reason to doubt its existence in muriatic acid; that this acid, instead of being fixed, was rendered more volatile by oxygene, and that, instead of becoming more, it was made less acid by every addition of oxygene; circumstances which do not seem to indicate that this is the acidifying principle of muriatic acid. I knew also, that Mr. Berthollet was,

was, at length, nearly convinced that the muriatic ought to be deemed a radical acid, which, by the means of a certain portion of oxygene, gained properties similar to those of the nitrous and sulphureous acids, and, being super oxygenated, acquired relative properties; similar to those of the nitric and sulphuric acids: I resolved, therefore, to try their different effects upon the topical blue, and for this purpose I mixed the acetous, sulphuric, and nitric acids, each separately, with a portion of it; and I found that, even in small quantities, they instantly destroyed the green and yellow colours of the dissolved indigo, and, by reviving it, rendered the mixture uniformly blue; producing, at the same time, a considerable effervescence. Muriatic acid, however, acted differently; for, though it produced some effervescence, it neither rendered the mixture, nor even its effervescing surface, which was covered with froth, blue, but both remained green, while secluded from the contact of atmospheric air, by being inclosed in a vessel well stopped; and I found it practicable to neutralize the alkali completely, without rendering the indigo unfit to produce a fast blue colour, or a green, upon yellows, if applied quickly; but when the topical blue, thus neutralized, was kept some time, the indigo, being deprived of the alkali which had held it in solution, gradually subsided in a great degree, and became unfit to be applied in this way. There is, however, I think, an intermediate degree to which the alkali may be neutralized, without precipitating the indigo, in any considerable quantity, for several weeks at least, and which will be sufficient to prevent the alkali from exercising

ercising any action injurious to the yellow colours upon which the blue may be laid. The topical blue made with sugar effervesced but very slightly when mixed with muriatic acid, and therefore it has, in this respect, an advantage over the blue made with orpiment. The fluoric is another acid, in which the existence of oxygen has never been proved, or made probable, otherwise than by analogy. This circumstance led me to try it also with the topical blue; when I found its effects very similar to those of the muriatic acid. The eighth part of a phial being filled with the fluoric acid, and some of the blue prepared with sugar, as before described, being poured upon it, no effervescence appeared, and the mixture remained of a yellowish green colour; cotton plunged in it imbibed, and continued of the same colour, until it was taken out and exposed to the air, when it gradually assumed a very deep, strong, blue colour, which, upon being washed in warm soap suds, was found perfectly fixed. The same experiment, with some variation of circumstances, was several times repeated, and always with similar effects; and upon the whole, the fluoric acid seems even better suited than the muriatic to neutralize the alkaline part of the topical blue, where it may be thought expedient to have it in a neutral state; though, I think, something short of this is all that can be wanted, or should be attempted, in the business of calico printing. I am sensible, that, though these facts afford new reason for not believing that oxygen is the acidifying principle of the muriatic and fluoric acids, they do not absolutely prove the contrary; because they may contain oxygen, so intimately united to their respective bases,

bases, as that it can neither be separated, nor left at liberty to manifest any of its usual properties; but, allowing this to be possible, we must not, I think, suppose it to be really the case, without more probability thereof than yet appears. This indeed was partly the case with vitriolic ether, which, being added to topical blue prepared with sugar, did not much change its colour, nor prevent it from being fixed in some degree on cotton.

Wishing to know what effects would result from a stronger action of pot-ash, lime, and orpiment upon indigo, I dissolved it with three times the usual portion of these agents, and having afterwards shaken the whole mixture well together, I filled a large transparent glass phial therewith (but without any gum), and having secured it from all contact with external air, by a glass stopper covered with wax, I left it in that state for three months, shaking the phial occasionally, that the more fluid part of the mixture (which soon became nearly colourless) might be acted upon more equally, by the lime, &c. at bottom; after which, the phial being opened, I found that the mixture (which gave a deep permanent blue to cotton, when first made) had become incapable of manifesting any colour by the contact of atmospheric air, or by the addition of sulphuric, fluoric, and other acids; the indigo having been not only deprived of the oxygene necessary to its colour, but probably rendered incapable of re-uniting with it as formerly, in consequence of a decomposition of its vegetable basis, or a new combination thereof with one or more of the agents in question, too

intimate to be overcome by any of the usual means of regenerating indigo. Here we have an instance of one of the most permanent of colouring matters losing its colour; not by any thing like *combustion*, which necessarily requires the presence and combination of vital air, but by means which seclude it from, and deprive it of, all such air.

In forming some of the indigo vats, it has been usual to employ a considerable quantity of madder and weld, though neither of them, in this way, can possibly do any good as colouring substances, their colours having no permanency without an aluminous, or other basis, as will be hereafter explained; they can therefore produce no benefit in any other way than as promoting fermentation; for which purpose many cheaper matters would prove infinitely more efficacious, particularly melasses, carrots, parsnips, shells of green peas, &c. &c.

It is to be observed, that all the preceding means of rendering indigo soluble, by abstracting a part of its oxygene, serve only to bring it back to the state in which it existed while retaining its green colour in the process of fermentation, before its minutest particles had been collected together, in a concrete blue form, by agitation, and the farther application of oxygene. I have already intimated a persuasion, that the colouring matter of the indigo plant, in this fluid state, is not only fit for dying, but that the blue colour dyed with it, would, like that of the isatis, or woad, be yet more permanent than that given by the indigo, after

after it has been made to assume a concrete form ; because its basis, even by the least destructive ways of dissolving it, will, I think, necessarily be in some degree weakened, as all other vegetable colours are found to be, by the action of such powerful agents as are requisite for that purpose ; and I conceive that the very durable blues which are known to be given by particular people in some parts of Asia and Africa, must be derived from the colouring matter of the indigo plant, employed when first extracted by steeping and fermentation. The Chinese are said to employ the indigo plant for dying in this way ; and it appears that the Africans employ it in a way nearly similar, at least with respect to the state of its colouring matter, applied as a dye.

According to Mr. Clarkson, " it is well known, at least in the manufacturing towns, that the African dyes are superior to those of any other part of the globe." " The blue (continues he) is so much more beautiful and permanent than that which is extracted from the same plant in other parts, that many have been led to doubt whether the African cloths brought into this country were dyed with indigo or not. They apprehended that the colours in these, which became more beautiful upon washing, must have proceeded from another weed, or have been an extraction from some of the woods which are celebrated for dying there. The matter, however, has been clearly ascertained : a gentleman procured two or three of the balls, which had been just prepared by the Africans for use : he brought them home, and upon examination
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found them to be the leaves of indigo rolled up, and in a very simple state.

M. Adanson, mentioning the indigo plant cultivated by the negroes of Senegal, says, these people do not take much pains to draw the dye out of this plant; they are satisfied with gathering the leaves at any time of the year, with pounding them in a mortar to reduce them to a paste, and with making them up into loaves, in order to preserve them dry. When they want to make use of them, they dissolve them in a kind of lye, made of the ashes of an unctuous plant which grows in their fields, and is by them called *rhemi* (*Portulacca Marina*, &c. *Plum. Cat. p. 6.*). This dissolution, adds he, imbibes a tincture of the indigo, into which they dip their linen cold, as often as they think necessary, according to the deepness of the colour. See his *Voyage to Senegal, the Isle of Goree, and the River Gambia.* 8vo.

The indigo plant, when used in the way which M. Adanson describes (with too much brevity indeed), seems to be in a state resembling that in which the isatis or woad is commonly employed, as before mentioned; and unless the freight would prove too expensive, I should think it might be advantageously imported in balls, like those mentioned by him, to assist in forming indigo vats, though it would not answer in this shape for producing what is called the Saxon blue, by a combination with sulphuric acid.

Of Saxon Blue.

Indigo dissolved by the sulphuric acid, acquires a more lively though a less durable colour

lour than it naturally possesses, or can be made to receive by any other means; probably because it thereby acquires an additional portion of oxygen. The application of this blue as a dye was first made by Counsellor Barth at Grossenhayn in Saxony, about the year 1740. He employed, besides indigo and sulphuric acid, lapis caliminaris and antimony, mixing them with the oil of vitriol first, and adding the indigo afterwards. According to some, he also employed allum; but all these additions being found useless, were afterwards laid aside.

M. Haussman observes, that a small piece of indigo put into a little sulphuric acid of proper strength, becomes very soon coloured upon its external surface, first of a greenish yellow, and afterwards of a deep green, and finally of a blue; that in evaporating indigo, which had been dissolved by this acid in a glass vessel placed on a sand heat, there escaped a portion of sulphureous or volatile vitriolic acid, and of hydrogen (inflammable gas), which upon applying to them the flame of a candle, gave slight marks of inflammation; that the expansion of the indigo, and separation of sulphureous inflammable vapours, during its solution by oil of vitriol, leave no room to doubt of the strong action of the latter upon the constituent parts of indigo; and he therefore concludes, that we should err in considering the indigo as having suffered no alteration by the sulphuric acid, and in comparing a solution of it in this way to those other solutions already described, in which the basis of indigo suffers little or no injury; that the blue dyed by these sulphuric solutions of indigo, can hardly be deemed a fast colour, since
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it is easily extracted by soap in boiling water, and changed by alkali to an olive colour, more or less yellow, according as the alkali is more or less caustic; and since the adhesion of this blue to linen and cotton is so feeble, that even cold running water will carry it off.

Bergman ascribes the want of greater permanency in the Saxon blue to the use of sulphuric acid not sufficiently concentrated. He used an acid whose specific gravity, compared to that of water, was as 1900 to 1000, and employed eight pounds of this acid to dissolve one pound of indigo. I believe, however, that he has been misled on this subject, and that Pœrner is much nearer the truth, when he says, that the best proportion for dissolving indigo is only four times its weight of good pure oil of vitriol; and that where more is used, the blue is less permanent. I am even inclined to think that the blue will prove more durable, if this last quantity of acid be diluted with an equal portion of water as soon as the indigo is put to it, and the mixture left in a warm situation 48 instead of 24 hours for the indigo to dissolve; because, by a slower and more moderate action, I think the basis of the indigo will be less weakened; at least I have frequently dissolved indigo in this way, and the colour has appeared to be more durable than when it was dissolved by an undiluted acid. Perhaps even a farther dilution might still leave the acid of sufficient force for dissolving the indigo perfectly. But this I shall endeavour to ascertain hereafter by more accurate experiments than I have yet made. The indigo being dissolved, Mr. Pœrner adds as many ounces of

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dried

dried pot-ash as there were of indigo in the solution, which produces an effervescence; and after twenty-four hours, he adds eight pounds and an half of water for each pound of oil of vitriol employed, and puts the whole into a glass vessel for use. Instead of pot-ash, I have used clean chalk, and this even in such quantities, as to saturate the vitriolic acid. The indigo was then precipitated with the chalk, and being collected in a solid mass, it was still capable of dying a blue on wood, though it took much more slowly than in the ordinary way of dying Saxon blue, in which the colour applies itself so rapidly to wool or woollen cloth, as to render it difficult, with the utmost care, to prevent its taking unequally; a defect which might probably be obviated by a small portion of chalk. It is to prevent this, that M. d'Ambourney advises, where deep Saxon blues are wanted, to pass the cloth at different times through vessels containing only what might suffice for weak colours, in order that the blue may, by these partial applications, be made to take with more evenness. Silk, dyed along with wool, takes a much weaker colour, (I mean with the addition of chalk,) because it has less affinity with the indigo than wool has. This preparation of indigo, however, would not give a deep blue, because being united with so large a portion of white calcareous earth or lime, the blue colouring particles could not be sufficiently condensed for that purpose. Pœrner conceives the Saxon blue to be rendered more durable by previously preparing the cloth with allum. The solution of indigo by sulphuric acid, is usually called by dyers chymical blue. It ought, however, according to the new nomenclature, to be termed

termed sulphate of indigo; a name by which I shall hereafter distinguish it. When applied to wool, the blue colour is much more permanent than while in a fluid state; for though a little manganese, added to the sulphate of indigo, instantly changed its blue to a brown colour, wool, which had been previously dyed blue with some of the same preparation, was not discoloured by the action of manganese dissolved in sulphuric acid. I do not know that a black was ever produced by the sulphate of indigo, or by any other preparation of that drug alone. Mr. John Wilson, who has greatly contributed to improve the art of dying at Manchester, maintains, that though a redundancy of colouring matter will increase the force and body of a colour, yet that no repeated dyings of blue will become black. I have, however, now before me two pieces of cloth, one of which is the deepest and purest black perhaps ever seen, and was dyed by me, very lately, from sulphate of indigo, employed alone, though in an unusual quantity; the other is of a fine Saxon blue, and was cut off from the first, before it had taken up so much of the blue colour as to become black. I lately found also, in making the topical blue, that a small piece of cotton, which I had thrown into the mixture, and which, being forgotten, had remained there forty-eight hours, was, when taken out, of a *full black*, so permanently fixed, that neither lemon juice nor alkalies seemed capable of impairing it. I could not in one or two trials afterwards succeed in producing a similar black on linen or cotton; and it must be remarked, that when I produced that which is the last mentioned, it was in a mixture where I had

at first put some manganese, to see whether it would promote the dissolution of indigo; and finding it did not, I had afterwards added more than the usual proportion of orpiment, one or both of which additions may have contributed to the black in question.

The sulphuric acid, or oil of vitriol, as commonly prepared, contains a small portion of the nitric, which, however small, necessarily does some harm in forming the sulphate of indigo. Mr. Chaptal observes, that he has seen the colour fail, and the stuffs intended to have been dyed spoiled by this fault in the sulphuric acid employed for that purpose, which ought therefore to be guarded against as much as possible.

The indigo of all others most preferred for Saxon blues, is the blue or Flora of Guatamala, which indeed is scarce ever employed for any other species of blue, at least in this country. The other kinds, and especially the copper, when mixed with oil of vitriol, effervesce sometimes very strongly, in consequence of the extrication of fixed air, the presence of which may easily be accounted for, by recollecting that lime is frequently employed to accelerate the separation and precipitation of the minute particles of indigo, while in the vessels called beaters: and here it will be proper that I should offer some conjectures on the cause of the different colours of indigo; and as a foundation for these, I must remark, that the flora or blue indigo of Guatamala is much lighter than the violet,

violet, and that this last is lighter than the copper-coloured. From the lightness of this *blue* indigo, and from its not effervescing with acids, when dissolved by oil of vitriol, there is the strongest reason to conclude that no lime is employed to accelerate the separation and precipitation of its colouring matter in the beaters; since if there had been any, it would have increased the specific gravity of the indigo, and by absorbing carbonic acid, would necessarily have caused an effervescence in making the sulphate of indigo: taking it therefore for granted, that no lime is employed to separate and precipitate the colouring matter, it would necessarily follow, that, to obtain such separation and precipitation, the agitation must have been continued longer than would otherwise have been necessary, and the unavoidable consequence would have been the combination of a larger proportion of oxygene with the colouring particles so exposed to it, than what takes place with those separated by lime: it will therefore follow, that indigo, obtained in this way, will contain a greater portion of oxygene than the other; and it seems natural to conclude that the blue colour is occasioned thereby. To ascertain, however, the justice of this conclusion as far as I was able, I took some of the lightest and bluest Guatamala indigo, and dissolved it by lime, pot-ash, and orpiment, as usual; one effect of such solution we know to be the taking away from the indigo a considerable part, at least, of its oxygene; and I accordingly found, as I have done in all cases where indigo was dissolved for the topical blue, that the dissolution was accompanied with a bright shining copper-coloured pellicle upon the

surface of the liquor, which of itself was of a greenish yellow underneath. The production of this pellicle may be easily explained by recollecting that the dissolved indigo, which has lost its oxygene, and become thereby of this greenish yellow, being at its surface in immediate contact with the oxygenous gas of the atmosphere, regains a part of what it had lost, and thereby becomes copper-coloured; but swimming as it does upon a mixture disposed to attract oxygene, it cannot in this state acquire and keep so much thereof as the indigo itself formerly had while it was of a blue colour; and therefore, so long as the body of the liquor remains yellow or green, the pellicle covering it will be only copper-coloured, though consisting of a colouring matter which was formerly blue, and which would have become so again, if, being dissolved, it had been thinly applied to linen or cotton, and brought sufficiently into contact with the oxygene of the atmosphere. As therefore this blue indigo had apparently become copper-coloured, only by having less oxygene than before, is there not from this circumstance an additional reason to conclude that the copper-coloured indigo, separated and precipitated by lime, is made of that colour only by its possessing a smaller proportion of oxygene than the blue indigo?—We might naturally expect, if the difference of colour arises from this difference in the proportion of oxygene, that the blue indigo would suit best for the sulphate of indigo, because it is to be dissolved by a farther application of oxygene contained in the oil of vitriol; and this is found to be the case, as was lately observed: and on the other hand we should suppose the
copper-

copper-coloured indigo to be best suited for the indigo vats and for the topical blue, because in these the dissolution is effected by taking away oxygene; and the less there is of it, the more easily will this be effected; and here also the choice and practice of the dyers accords with this hypothesis, as they constantly employ the copper-coloured indigo for these last purposes.— But though the *blue* indigo of Guatamala is the lightest and most valuable, because its colouring particles are not intermixed with lime, and are but in a small degree mixed with other matters which might give it weight and bulk without contributing to its tingent powers, yet this is not the case with all *blue* indigo; for in most countries it is now an invariable practice to precipitate indigo by lime-water; and as a desire to extract as much of it as possible from the plant, very frequently induces the operator to carry its fermentation in the steepers too far, by which the colouring matter acquires an undue portion of oxygene, so as afterwards to appear blue, even when precipitated by lime-water; and as this matter is moreover debased by being mixed with other vegetable substances, extracted from the indigo plant by too much fermentation without affording colour, it happens that indigo of very inferior qualities often appears blue.

Bergman, Quatrenere, &c. have endeavoured by analysis to ascertain the component parts of indigo; and M. Berthollet has given a sufficient account of the results of their operations; from all which, corrected by more recent discoveries, it appears, that pure indigo consists of a considerable

derable portion of hydrogene, a little azote, about one-thirtieth of its weight of iron, a very large proportion of the basis of charcoal, and a considerable one of oxygene; which last, I conceive, in these operations to have become united to the carbonic basis, and to have converted it into charcoal. M. Berthollet ascribes the permanency of the colour of indigo to its abundance of charcoal; and he clearly exposes the error of those who have attributed its colour to the very small portion of iron contained in it. The stability and difficult solubility which the colouring matter of indigo acquires by combining with oxygene, seem to resemble, though in a less degree, what the basis of charcoal acquires by a like combination; but in this last the oxygene is so much more intimately combined, that it cannot be separated by the means which separate the oxygene from indigo, in making the topical blue, as I have found by repeated trials upon charcoal, and therefore it can only be acted upon in the last of the two ways of dissolving indigo; I mean by the farther application of vital air, so as to convert it into carbonic acid gas. The first mention of indigo, as known in this country, which I have observed, is in the act of the 23d of Queen Elizabeth, cap. ix. where it is called "*Ankle, alias Blue Inde.*"

The Genipa Americana, Linn. is a very widely-branching lofty tree, growing spontaneously in different parts of Guiana and Brasil, where it is known by different names; in Surinam by that of tapouripa; in Demerary by the name of launa;

launa; and in Brasil, according to Marcgrave and Piso, by the names of janipha, janipaba, &c. It bears a fruit nearly oval, of the size of a large lemon, covered with a greenish ash-coloured skin. This fruit, when ripe, assumes very nearly the appearance and texture of a ripe medlar or a baked apple; and being replete with a moderately acid juice, is sometimes eaten to quench thirst. The substance of this fruit, while unripe, is hard, colourless, and somewhat bitter; and when cut open there is found in the centre of it a number of seeds in a small cavity, surrounded by a soft pulp, the surface of which has a slight blue tinge, probably occasioned by air collected in the cavity where the seeds are placed. Being at Surinam in the year 1770, I took some of this pulp, and pressing the clear colourless juice upon pieces of white linen and cotton, I found that, though the spots wetted therewith at first shewed no colour, yet being hung up to dry, in less than twenty-four hours they had acquired a deep strong blue, very much resembling that dyed with the isatis or woad. This blue I tried in vain to discharge, or even weaken, by a multitude of washings with soap and water, by the application of lemon juice, and by long exposure to sun, air, rain, &c. in a climate where at least the first of these agents exerts the most powerful action upon colours; and by repeated trials I convinced myself that the blue obtained from this fruit, even by the most simple topical application of it, was as permanent as any obtained from the indigo plant.

This blue has long been used by the savages of Guiana, Brasil, &c. for painting their skins
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of a dark blue or violet colour, as (according to Cæsar) the woad was used by the ancient Gauls and Britons for the same purpose. During my first residence in Guiana, in the years 1763, 4, 5, and 6, I had often observed the native inhabitants of that country staining their bodies with this colour, which was usually contained in calabashes or gourds, in which they had previously macerated the fruit of the genipa, or its pulp, with water for some days before. I had myself stained my fingers with it, and found that I could not remove the colour in any degree by washing, though after nine or ten days it gradually disappeared, doubtless by an abrasion or wearing away of the substance of the cuticle to which it adhered; but at that time I did not attend much to the manner in which this happened, and suffered myself to adopt an opinion generally prevailing in that country, that this colour would in all cases spontaneously disappear at the end of eight or nine days; an opinion which had been propagated by Clusius, Piso, Marcgrave, Hernandez, Rochfort, and others; and which must, as I am now persuaded, have originated from the circumstance of its usual disappearance at those periods when applied to the human skin, by an abrasion thereof.

It was not until my second visit to Guiana that I first thought of the application of this blue to the purposes of dying and callico printing; and though I did not then remain long in that country, and had no opportunity of seeing this blue prepared or applied by the savages, who have much less intercourse with the inhabitants of Surinam (where I alone resided) than with any
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of the neighbouring colonies, I made a sufficient number of experiments to ascertain, beyond all possibility of mistake, that the fruit of the genipa affords, not a fugitive colour, as had been and probably now is universally believed, but a strong permanent blue similar to that of indigo, both in its nature and in the means by which it becomes visible; I mean by the absorption of oxygene: and when I consider the magnitude of the genipa tree, together with the quantity and size of its fruit, I cannot help thinking that plantations of it would prove highly beneficial, on account of the blue dye which the fruit would afford, either in the form of indigo by maceration, &c. or when gathered, cut, and dried, so as to prevent putrefaction, and admit of their conveyance to Europe. A gentleman of character and fortune, who resided some time in Bengal, and was the proprietor of a large establishment for callico printing in that country, being returned from thence about three years since, favoured me with a piece of indigo of a very good quality, which he assured me was obtained from an East Indian tree, one of the leaves of which he at the same time shewed me; and from its appearance, as well as from other circumstances, I have very little doubt but it is of the same species as the *Genipa Americana*; more especially, as there is a tree growing plentifully on the coast of Malabar, and described in the Hort. Malabar. by the name of *panitsjicamaram*, which appears in every respect to resemble the genipa, excepting that the authors of that work have omitted the mention of any colouring property in the fruit of the Malabar tree,

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an omission which may have proceeded from several causes.

During my last short visit to Guiana, I did not find any of the fruit of the genipa perfectly ripe, and my experiments were necessarily made only upon those which, though they had nearly attained their full growth, were hard and apparently colourless. Whether the soft juicy pulp of the ripe fruit is more or less effectual than the pulp of the unripe fruit for giving colour, I know not; nor do I recollect whether the savages of Demerary and Essequebo, in preparing this colour, macerated the pulp of the ripe or the unripe fruit for that purpose. I have, since my return to Europe, been informed that the bark and leaves of the genipa tree, by maceration, afford a blue like that of the fruit. Should this prove true (which seems probable), it would doubtless render the cultivation thereof very profitable.

Hogs and other animals, feeding upon the fruit of this tree when it falls spontaneously on the ground, are said to have their bones stained with its colour, as happens to animals feeding upon madder, and some other colouring matters.

Mr. Martin Lister (in the VIth Vol. of the Philosophical Transactions, page 2132,) mentions that “ the seed husks of *glastum sylvestre*,
“ old gathered and dry, being diluted with wa-
“ ter, stain a blue, which upon the affusion of
“ lye strikes a green, which green or blue, be-
“ ing

“ing touched with the oil of vitriol, dyes a purple; and all these colours (says he) stand.”—He adds, that “on the tops of the fungus tuberosus (so called by Mr. Wray in his Catalogue of the Plants of England), are certain red knots, which, upon the affusion of lye, will strike a purple, and stand.” The juice of some of the mushrooms also becomes blue when exposed to atmospheric air. The same effect, according to Sennebier, happens to the milky juice of the tithy malus (euphorbia, Linn.).

It is mentioned somewhere in the Swedish Memoirs, by Cronsted, that the stalks of the polygonum fagopyrum, Linn. by fermentation in water, afford a blue which did not change either by acids or alkalies.

Brown, in his History of Jamaica, p. 143, observes, that “the pulp of the berries of the randia aculeata, Linn. (called in that island the indigo berry, and which generally grow very numerous on the smaller branches of the plant), is very thick, and stains paper or linen of a fine fixt blue colour. I have tried it (continues he) on many occasions, and have always observed it to stand, though washed with either soap or acids; but it does not communicate so fine a colour with heat. It would prove (he adds) an excellent fixt blue in all manner of paints and prints, if it could be obtained in any quantity; but the berry is not very succulent, and the people as yet are not very industrious in these parts.” Having had no opportunity of trying the effects or properties of these berries, I can only recommend

mend them to the notice of others, which they seem to deserve.

The gentleman who favoured me with a specimen of indigo, obtained from an oriental tree, which I concluded to be that called panitsjica-maram in the Hort. Malabar. as mentioned at page 141 of this volume, gave me also a very small piece of a hard green substance, which had been sent to him from some part of the East Indies, and which he called a Green Indigo. Upon seeing it, I flattered myself with a hope of its proving to be what the late Mons. de Poivre mentions in a little work, published under the title of "*Voyages d'un Philosophe*," &c. as obtained by the inhabitants of Cochin China from a plant called *t'ai*, which, when macerated and fermented like indigo, yields a *green* fecula, capable of dying a fine, as well as a lasting emerald or green colour. The quantity of this green substance thus put into my hands, was much too small even for a single decisive experiment. I however divided it into three parts. One of these I put into boiling water, which appeared to have no action upon it; but it was afterwards dissolved by a little oil of vitriol like common indigo, producing, however, a green, instead of a blue colour. A second of these parts I dissolved with a little caustic alkali and orpiment, in order to see whether, excepting the difference of colour, it would possess properties similar to those of indigo when dissolved by the same means, and like the latter be able to produce a fixed colour on linen or cotton by topical application. This however it did not seem to be capable of doing: the remaining part I put into
a little

a little spirit of wine, which dissolved a portion of it, though very slowly; a circumstance in which it differs materially from indigo, and seems in some degree to resemble that green-coloured secula which some plants afford, and particularly the cruciform, when fermented like the indigo plant in warm weather. I confess, however, that these experiments were made on such very small quantities of the substance under consideration, that very little dependance ought to be placed upon them. But this is certain, that if a green colouring matter exists, and can be discovered with properties in other respects similar to those of indigo, it will be a most important addition to the *Materia Tinctoria*.

No substantive vegetable yellow has been, as I believe, ever employed for dying in Europe, though there are accounts of vegetables, growing in distant countries, which seem capable of affording such yellows with advantage. Mr. Clarkson, in his essay on the impolicy of the African Slave Trade, relates, that "a gentleman, resident upon the coast, (of Africa,) ordered some wood to be cut down, to erect a hut: whilst the people were felling it (continues Mr. C.) he was standing by, and, during the operation, some juice flew from the bark of it, and stained one of the ruffles of his shirt. He thought that the stain would have washed out; but, on wearing it again, he found that the yellow spot was much more bright and beautiful than before, and that it gained in lustre every subsequent time of washing." Pleased with the discovery,

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he

he sent home a small sample of the bark, which
“produced a valuable yellow dye, *far beyond
any other ever in use in this country.*”

Mr. Clarkson adds, that this gentleman “is
since unfortunately dead, and little hopes are en-
tertained of falling in with the tree again.”
The colour mentioned in this account, if there
be no error in it, must have been of that kind
which I have denominated substantive colours,
as capable of being fixed by dying, &c. without
the aid of any aluminous, or other basis.

M. du Pratz, in his history of Louisiana, also
mentions a tree, or shrub, seldom exceeding the
thickness of a man's leg, the wood of which,
he says, is yellow, and yields a water of the
same colour if cut in the sap. Both the wood
and the water, he says, have a disagreeable smell;
and the former is used by the natives for dying,
first cut into small pieces and boiled in water,
into which they dip feathers, hair, &c. He calls
it ayac, or stinking wood; and as he mentions
nothing of the use of allum, or any other basis
or mordant, this, if his account be accurate,
must also be a substantive colour. I fear, how-
ever, that the information of persons, not parti-
cularly acquainted with the subject, cannot be
much relied upon respecting the natures and
properties of dying drugs.

The roots and bark of the *Berberis vulgaris*,
Lin. afford a yellow to wool without any basis,
but it has not the smallest degree of permanency
against the action either of air or soap. This
shrub

Shrub indeed furnishes a remarkable instance, to shew how little can be discovered respecting the colouring properties of plants from their external appearances. A similar instance lately occurred to me in the wood, bark, and root, of the *Zantoxylum clava Herculis*, Lin. (the tooth-ach tree, or japan pepper tree,) every part of which is strongly coloured of a most beautiful yellow; but having procured some of it for trial, I could extract but little colour from it, notwithstanding its seeming abundance of tingent matter; and the little which I did extract, was like that of the *Berberis*, utterly incapable of forming the least union with any basis, or of resisting the action of air, or of soap, in any degree.

The seeds of the *Bixa Orellana*, (growing spontaneously in different parts of Guiana,) are covered with a reddish pulp, which is collected and sent to Europe in different forms, under the names of annotta, arnotta, and roucou. It is principally employed for dying silk, and sometimes for cotton; though its colour, by all the ways and means of applying it hitherto discovered, is so fugitive, that perhaps it would be better if it were never employed even for dying silk. It partakes so much of a resinous nature, as to dissolve but very imperfectly in water; and therefore at *least* an unequal weight of pot-ash is employed to render it soluble in that vehicle, and afterwards the silk or cotton is dyed therein without any aluminous or other basis*. The

* The liquid sold in different parts of the town, under the name of "Scott's Nankin Dye," appears to be nothing but annotta dissolved by pot-ash in water.

colour of annotta becomes less red, and more inclined to the orange, when separated from the seeds by maceration, in water, as is usually practised; and by the addition of pot-ash, it is made to incline still more to the yellow hue. This last change may, however, be readily overcome by adding any of the different acids to the dying liquor, after sufficient colour has been taken up by the silk or cotton dyed therein; though argol or tartar is generally preferred for this purpose, because it not only raises the colour, but seems to render it a little more fixed. It is remarkable, that though the colour dyed with annotta fades very fast by exposure to air, it powerfully resists soap, and the action of the strongest acids. And it certainly affords one, among several instances, of colours which decay by causes very different from combustion; because linens and cottons dyed in the usual ways with annotta, and afterwards wetted with oxygenated muriatic acid, instead of suffering a diminution of colour, were enabled by it to bear exposure to the weather longer, and with less injury than pieces of the same dyed linens and cottons, to which none of the oxygenated acid had been applied, as I observed on repeated trials: and when we see that the colours of indigo and madder, the most durable of all those given by the art of dying, are speedily destroyed by this oxygenated acid, and that it has no such destructive action upon some of the most fugitive of all dyed colours, (such as that of annotta,) we certainly must conclude, that the colouring matter of this last substance is constituted very differently from that of madder and of indigo, and susceptible of being preserved as well as destroyed

stroyed by very different means. The destruction, therefore, of all dyed colours, cannot justly be imputed to any single cause, be it combustion or any other; nor ought we to consider the oxygenated muriatic acid as acting on colours in the same way as air, when one preserves what the other destroys. The fresh pulp of the *Bixa Orellana* taken immediately from the shrub whilst growing, and applied to cotton without the addition of any alkali, seemed to afford a colour more lasting and higher, or more approaching to the red, than what can be dyed from the pulp separated by maceration, as is done in producing the common annotta. The greatest consumption of this article, at least in Great Britain, is, in giving a kind of yellowish orange to cheese, for which it is very suitable, because it is harmless, and nearly tasteless.

The *Lawsonia inermis* of Linn. has long been used throughout India, Persia, Arabia, Egypt, and in many other parts of Africa, for giving a reddish stain to the nails, lips, &c. It is the *Ligustrum Ægyptiacum* of Prosper Alpinus, and the *Hinna* of the Arabians. Sir William Jones relates, that being at the island of Hinzuan or Johanna, and observing a very elegant shrub, about six feet high, not then in blossom, he learned that it was the "*Hinna*," of which he had read so much in Arabian Poems. "Musa (one of the inhabitants, says he) bruised some of the leaves, and having moistened them with water, applied them to our nails and the tips of our fingers, which in a short time became of a dark orange scarlet."—Nieuhoff says, "they prepare the tinc-

ture by steeping the leaves after they have been rubbed small upon a marble stone, in fair water, mixed with a small quantity of lime."—"With this (continues he) the Turks and Persians also dye their horses' tails." This shrub, according to Adanson, is called soudenn by the negroes of Senegal, where it is used both by the men and women to give their nails a red stain, which lasts until the substance of the nails changes by growth. As the colour of this shrub requires no kind of basis or mordant, it must naturally belong to the class of substantive colours.

I lately received a few ounces of small seeds, inclosed in a flea-coloured husk, but without any information respecting the plant on which they grew. They were brought from the coast of Barbary, where, as I was informed, they are used in dying red or pink colours. In two or three small trials which I made with them on silk, they appeared to possess a substantive colouring matter, similar in some respects to that of safflower. At first I thought they might be the seeds of the *Gardenia florida*, which, according to the accounts of Mr. James Cunningham, who formerly travelled into different parts of the East-Indies in pursuit of natural curiosities, the Chinese employ for dying *scarlet*, under the name of *umki**. I found, however, that this

* Dr. Plunkenet, in his *Amaltheum*, page 29. says, "Semina tinctoribus inserviunt us enim ab indigenis Sineensibus optime tingitur nobilis ille color, quem *escariatinum* nostrates vocant, ut nos monuit vir multiplicis industrie atque indefessi laboris hac in parte, D. Jacobus Cunninghamus."

could not be the case, as the seeds of the *Gardenia* grow inclosed, several of them in one common capsule, involved in a rich coloured mucilaginous substance; whereas the *Barbary* seeds evidently grow without any such inclosure. I cannot discover whether the seeds of *Gardenia* ought to be considered as a substantive or an adjective colouring substance; all accounts respecting them being defective.

There are several species of *Lichen*, or moss, capable of producing substantive colours of various complections, and of different degrees of durability. M. Westring appears to have lately made numerous experiments in dying wool and silk with the different mosses which grow abundantly in Sweden. His first publication on this subject, in the transactions of the Stockholm Society, relates to his experiments on the mosses denominated *Leprosi*. He found ammoniac or volatile alkali to be the most active dissolvent of their colouring matter: mordants appeared hurtful, as the gummy parts of the mosses did not bear the action of acids. Their colours were various; and some of them yielded their colouring matters by maceration in cold water only; and these were afterwards as capable of being fixed by dying, as those extracted by ammoniac. Some of the mosses in this country, (particularly the *Lichen petræus purpureus* *Derbientis* of Parkinson *,) and many in America, not yet brought into use, seem capable of being employed with advantage in dying. But of these

* Cork or arcel.

I shall say more in a future volume; and in the mean time refer my readers to Mr. Berthollet's work for what is at present known respecting the two species usually employed for the preparation of archil. I mean the *Lichen roccella*, and the *Lichen parellus*, Linn.

To this class also belongs the *Carthamus tinctorius*, or safflower; but my own experiments having afforded nothing of importance respecting it, I shall in like manner refer my readers to Mr. Berthollet for information on this subject.

There is a species of colouring matter diffused in greater or lesser proportions through the barks and other parts of almost all trees and shrubs, and which, without any basis or mordant, permanently dyes or stains wool, silk, cotton, and linen, of that particular kind of colour which the French call "*fauve*," (fawn-colour,) and sometimes *couleur de racine*, ou de *noisette*, (root, or hazel-nut colour.) This being naturally blended with some of the more valuable colours of vegetables, frequently does harm, by degrading or obscuring them. It is found most abundantly in the peeling or husks of walnuts, (*Juglans regia*), in the roots of the walnut-trees, in alder, bark, &c.; and it seems to acquire both body and permanency by attracting and combining with the basis of pure air. Mr. Berthollet has, however, treated so fully and so well of the properties of this kind of colouring matter, when applied substantively, that I cannot do better than refer my readers to that part of his

his work which relates to it; observing at the same time, that the colouring matter in question, though capable of being permanently fixed without any metallic or earthy basis, does however, in some instances, acquire new and more useful properties when applied with a basis adjectively, which I shall more particularly notice hereafter under the proper heads.

There are three species of poisonous shrubs or vines growing in North America, and containing in their stems, leaves, &c. a white milky juice, which when applied to linen, cotton, or silk, produces a stain, which soon becomes of a full, strong, lively, and durable *black colour*, incapable of being discharged by repeated washings, or impaired by the weather. These are the *Rhus vernix*, (growing likewise in Japan;) the *Rhus radicans*; and the *Rhus toxicodendron*, Linn. Some trials which I formerly made in America seemed to indicate the last of these as affording the deepest and most permanent black. But in all of them this colour probably depends on the addition of oxygene to the colourable matter; an addition which, in the formation of indigo, produces only a blue, whilst in the present instance it changes a white milky juice to the greatest possible extreme, by rendering it of a full strong black.

The fruit or beans of the *Avicennia tomentosa*, Linn. called Malacca beans, or marking nuts, have long been used in the East-Indies for marking upon cottons, &c. They contain each a small kernel, surrounded by a viscid blackish juice, which in some that were lately given to me,

me, by a gentleman who had been possessed of them near ten years, very much resembled tar, both in colour and consistence; though it seems probable that in the fresher beans the juice is more fluid, and of a lighter colour. Having extracted some of this juice, I applied it topically to a bit of white callico, which it penetrated thoroughly, and being suffered to dry, it was both washed and boiled in soap suds, and afterwards exposed to the weather for the space of two months, during which time it had become decidedly black, (probably by attracting oxygen;) but as the juice had been at first so thick and viscid, it seemed more like a painted than a proper dyed or stained colour. Osbeck says, that in using these beans, the letters or marks should be covered, while wet, with quick lime, which enables them to bear washing, and prevents the juice from hurting the stuffs marked with it. Whether lime be necessary for these purposes may, I think, be doubted, since, though I used none, the colour was not weakened by washing, nor did the cotton appear to have received any injury: and respecting any injury to the stuffs, this was an effect which seemed of all others the most unlikely, as the juice in question, which I tasted, had not the smallest degree of acrimony.

Kœmpher (Am. p. 739.) has improperly called this "*Anacardus Orientalis*;" it being a pod-bearing tree, very dissimilar to the true *anacardium* or cashew nut, which also affords a juice capable of giving a lasting brown stain to linens and cottons. Several other vegetables produce effects of the same kind, but they either
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do it so sparingly, or the colours they afford are of so little value, as to deserve no particular notice.

CHAP. VI.

Of Mineral Substantive Colours.

“ Rien n'est plus facile dans les sciences fondées sur l'expérience que de multiplier les faits particuliers, mais ces faits ne sont dignes d'attention, que lorsqu'ils servent à conduire à des vérités générales, ou que présentant au contraire, des singularités nouvelles & imprévues, ils deviennent un objet de recherches.” HIST. de l'ACAD. R^e, &c. 1777.

EACH of the metals and semimetals is capable, when dissolved, of becoming a basis or mordant, for fixing and modifying some at least of the different adjective animal or vegetable colouring matters, with more or less advantage, by dying. But besides this property, which will be made a subject of future consideration, several metals and semimetals, or rather their solutions or oxides, are capable of being united and fixed directly in the fibres of linen, cotton, silk, and wool, and of thereby producing various permanent substantive colours. It is indeed true, that hitherto but few metallic preparations, excepting those of iron and copper, have been used in this way, or for this purpose; I mean that of giving substantive colours.

Iron,

Iron, by whatever means dissolved, possesses so much affinity to linen and cotton, that when applied to them its oxide or calx decomposes and fixes itself permanently in their fibres, and thereby produces colours differing considerably from each other, according to the different states in which the oxide may have been applied, particularly in respect of the portion of oxygene combined with it. But as the oxide of iron, in *all states, and however obtained*, is strongly disposed to attract the oxygene of the atmosphere, its different colours, by this addition, soon lose their peculiar shades or variations, and acquire the rusty colour of what is commonly called *iron mould*. This addition, moreover, soon renders the oxide in some degree corrosive, and joined perhaps to the rigidity which it occasions by concreting in the fibres of wool, silk, cotton, and linen, it disposes them to become feeble, or, as it is commonly expressed, *rotten*. There are few, if any, who have not observed instances of this effect from spots of what is called iron mould on linens, &c. which produce holes, long before any appear in other places. But where iron is used in dying, merely as the basis of animal or vegetable colouring matters, these last, by combining with its particles, lessen their disposition to attract oxygene, and by keeping them farther asunder, so far prevent their concretion, as in a considerable degree to obviate the rottenness in question; though there is but too much reason to fear, that even in this way stuffs dyed with a ferruginous basis or mordant, are the less durable from that circumstance, and that it is from the use of this metal that the rottenness

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ness so generally complained of, as accompanying the black dye, principally results.

The use of what is commonly called iron liquor, (acetite of iron,) made by dissolving that metal in vinegar, alegar, &c. is well known both as a mordant or basis for black, purple, drab, and olive colours, &c. in callico printing, and also as a topical substantive colour or stain for application by the block and pencil in callico printing. This latter use of it, however, cannot be too much discouraged, for the reasons already alleged.

Lately, the acid of tar has been employed in this country to dissolve iron, and produce an iron liquor, which is used by callico printers, to give a substantive topical stain of a darker brown than what the common iron liquor produces. A similar effect may be produced by combining arsenic with the oxide of iron; but no benefit can result from this, equal to the danger of putting that poisonous drug into the hands of careless, and sometimes ill-disposed people.

At Manchester, substantive buff colours are dyed with a diluted solution of iron, by the nitric acid; first neutralizing it by an addition of pot-ash, and taking care, after the dying is performed, to wash off all the loose or superfluous particles of iron, that it may not injure the cottons by an excess in quantity. But the colour dyed in this way is certainly accompanied with some degree of rottenness, from the causes before mentioned, and liable to other inconveniences,

veniences, particularly that of turning black, if accidentally wetted by tea, &c.

Iron dissolved by muriatic acid, affords a greenish-coloured solution; and this being applied to linens and cottons, the iron fixes itself, and attracting a considerable portion of oxygene from the atmosphere, produces a very fine yellow stain. But a single washing destroys this beautiful yellow, (which depends wholly upon the union of muriatic acid, oxygene and iron,) and reduces it to the common rusty iron mould colour. Indeed this defect, as has been already mentioned, attends all the preparations of iron, however various their colours may be, at first; and therefore, as well as in consideration of the rottenness which they occasion, when applied substantively to linens and cottons, I am much more inclined to discourage their use in this way, than promote it by any farther explanations.

The uses of copper, as a basis in dying adjunctively, will fall under our consideration hereafter. At present I have only to mention its properties as a substantive colouring substance. The solutions of this metal readily unite to the fibres of linen and cotton when applied to them; and being so united, whatever may have been their original colours, they speedily attract oxygene from the atmosphere, and are thereby rendered green; a colour which, when produced in this way, is sufficiently durable upon linen and cotton, so far as respects the impressions of air; but, when washed with soap, the oxide of copper is readily disengaged from the
linen

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linen or cotton, and combining with the soap, which it curdles, seems to form with it a kind of green paint.

In this respect, however, the solution of copper by ammoniac, (volatile alkali,) differs I believe from all the other solutions of that metal; for when it is applied to linen or cotton, though by absorbing oxygene it soon loses its fine blue colour and becomes green, yet soap in washing does not separate or discharge the ammoniated calx, except by very slow degrees; so that, with care, it will resist a great number of washings without much diminution of its colour; and as it suffers nothing from the action of air, I think it might be advantageously employed, particularly on fine muslins, as affording a *very delicate* though *pale* substantive green, and especially since in this way it may be applied so very readily and conveniently. Water should be made to dissolve as much ammoniac as it can for this purpose, and the solution should be fully saturated with copper; after which it must be sufficiently thickened with gum, and kept in bottles, closely stopped, pouring it out by a little at a time when wanted for penciling. I have sometimes thought the colour somewhat improved, when, instead of dissolving copper in its metallic state, I dissolved the nitric calx of that metal by volatile alkali; but at other times this supposed improvement has appeared doubtful.

Substantive copper-greens have sometimes been dyed from sulphate of copper with lime and soap suds, employed so as to precipitate the particles of copper upon the stuffs intended to be dyed; but the colour given by these means
is

is so fugitive, that it deserves no farther notice.

There are several of the other metals and femimetals which, when precipitated or depofed upon animal and vegetable fubftances, in a kind of middle ftate between the metallic and the oxidated, combine therewith, and produce very durable fubftantive colours. To effect this precipitation, it is neceffary that the feveral metallic oxids fhould be deprived of a confiderable part of their oxygene; and this happens to them more readily, when applied to wool, (from its animal nature,) than when applied to filk; and when applied to the latter, (from its mixed nature,) more readily than if applied to linen and cotton. But vegetable fubftances are eafily rendered capable of producing this effect, by firft impregnating them with either animal, alkaline, or inflammable matters; for which reafons will readily occur, after what has been heretofore fo often explained. In thefe cafes, light frequently concurs with the matters laft mentioned, to haften a feparation of the oxygene. Hallor obferves*, that characters traced on writing-paper with a diluted nitro-muriate of gold, began after a few hours expofure to the air, (he probably fhould have faid light,) to manifefit colour, and foon after became of a very dark violet—"violet *forcé prefque noir*." But when fhut up in a clofe box, he fays, the writing did not become vifible during feveral months. And he adds, that the like happened to characters written with a diluted nitrate of filver, though they became very vifible in the fpace of an hour when ex-

* Mem. de l'Acad. R. &c. 1757

posed to the sun's rays. See Mem. de l'Acad. R^e des Scien. de Paris, 1737.

Dr. Brugnatelli (Ann. de Chymic, tom. iii.) also mentions, that characters written with a solution of gold become of a fine purple when exposed to the vapour of spirit of wine (which deprives them of oxygene), and of a deep red colour in the hepatic or sulphureous inflammable air.

Every one who has had much occasion to handle the nitro-muriatic solution of gold, will probably have found his fingers sometimes stained with it of a fine reddish purple colour. This has happened to mine very often, and nothing but the wearing off or abrasion of the skin would ever remove it. By impregnating linens, cottons, and silk, with animal, inflammable, alkaline, and some other matters, they are enabled to receive fine durable purples by the like solution. The yolk, as well as the white of egg, having been beat up with water and a little sugar, I soaked some muslin therein, and when dry, applied a diluted nitro-muriate of gold to it, topically, which produced a very fine strong purple. Cotton, impregnated with lintseed oil, received from the like application a strong violet colour, as it did when impregnated with soda, and acidulous arseniate of pot-ash (Macquer's arsenical neutral salt): being impregnated with soda, sulphure of pot-ash, and sugar, the cotton received an olive brown by the same application; and a blackish brown, when impregnated with alcohol and liver of sulphur. Having soaked cotton and silk in a diluted muriate of

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tin,

tin, I plunged them into water which contained a little powdered chalk, and pressing out the water, dried them; this being done, I applied to them topically, by the pencil, a diluted nitromuriate of gold, which produced, wherever it was applied, a strong lively purple colour, apparently of a very durable nature. This effect is similar to that which takes place when the solutions of gold and tin are mixed together, and the metallic oxides having a stronger attraction for each other than for their acid solvents, unite, and, by reason of their gravity, precipitate together in the form of a purple powder, which consists of both of these oxides, though the colour is wholly owing to that of the gold.

Leeuwenhoek mentions (Philosoph. Transact. Vol. xxiv.), that by touching nitrate of silver, his fingers were stained black; and that finding it impossible otherwise to remove the stain, he cut off and burnt the skin, and then examining it by a microscope, he found the silver revived in a multitude of little globules.—“ I have lying on my desk (continues he), a linen handkerchief, which was stained with aqua-fortis, impregnated with silver, with a large black spot about as large as a shilling;” and he adds, that having ineffectually tried to discharge the colour by six washings, and by laying the handkerchief out to bleach, he cut out the stained part, burnt it to coal, and viewing it by a microscope, saw thousands of fine silver globules therein. The effect here mentioned to have been produced upon the skin, accords with that which solutions of silver are known to produce in blackening hair, and other animal substances;

stances; but in reading this account, I thought it extraordinary that clean linen, impregnated with no animal, inflammable, or alkaline matter, should so far deprive nitrate of silver of its acid, as to produce the effect described; and I repeated the experiment several times without success. At length, however, I took a silver tea-spoon, which had stood half filled with aquafortis for several weeks, and which on the hollow inside was become almost black by it, and by the oxygene of atmosphere which it had attracted, and having poured out the more fluid part of the solution, I rubbed a bit of cambric against the wet oxidated hollow surface, and hanging it up for a few days in the open air, on the sunny side of a wall, I found the cambric permanently stained of a very dark violet colour. A fine piece of cotton, however, by the same means received but a very slight discoloration. Though cotton, when impregnated with soda and the acidulous arseniate of pot-ash, received a strong durable slate colour by being touched with diluted nitrate of silver; a drab colour by the same means when impregnated with soda and sugar; a dark olive brown, with sulphure of pot-ash (liver of sulphur), and spirit of wine; the same with soda, liver of sulphur, and sugar; and being impregnated with white of egg, beat up in water with sugar, the cotton received from the nitrate of silver a very strong brownish black; and when caustic vegetable alkali was added, it became a little blacker. The yolk, instead of the white of egg, produced nearly the same effect. All these colours were often washed, and exposed for a long time to the weather, without being changed.

The oxides of mercury very easily give up their oxygene, and therefore they are readily precipitated by the means before mentioned upon vegetable as well as animal substances, affording generally either black or dark colours, though of but little permanency, because the residue of their oxygene soon separates, and the mercury recovers its fluid metallic form. Nitrate of mercury applied to cotton, which had been impregnated with soda, produced at first a yellow, which soon changed to an olive, and being washed with soap, to a full black colour; but after a few days exposure in the open air, it almost entirely disappeared. On cotton, impregnated with soda and sulphure of pot-ash, it immediately produced a black, which, by washing and exposure in open air, changed in about ten days to an olive, and soon after disappeared. On cotton, impregnated with sulphure of pot-ash and spirit of wine, it also produced a black, which disappeared like the former; and with caustic vegetable alkali it produced nearly the same effect. With orpiment, dissolved by pot-ash, it produced a very *deep black*, which stood two or three weeks exposure to the weather; after which the mercury began to revive, and the colour to disappear in spots.

Nitro-muriate of Platina, applied to cotton and silk, impregnated with soda; with soda and liver of sulphur; with soda and the acidulous arseniate of pot-ash; with orpiment dissolved in pot-ash; with liver of sulphur and alcohol; and with lintseed oil, severally, produced various purples, olives, dark and reddish browns, most of which appeared sufficiently durable.

Nitrate

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Nitrate of cobalt applied to cotton, impregnated with soda ; with soda and acidulous arseniate of pot-ash ; and with caustic vegetable alkali, produced lively pink and rose colours, which stood washing and exposure to weather for a considerable time.

The oxide of cobalt, dissolved by muriatic acid, and applied to cotton impregnated with soda, when held to the fire exhibited the most beautiful green, which, as the cotton cooled, changed to an apple-green ; then passed through all the shades of yellow, and became a kind of pale buff colour, which the oxide retained after the cotton had been washed with soap ; but then on being heated, it was found to have lost the property of becoming green, though on dipping it into a diluted muriatic acid, it immediately regained and exhibited the same property. These effects are connected with those which similar solutions of cobalt produce as sympathetic inks ; though I confess myself dissatisfied with all the explanations hitherto given of them. Perhaps I may offer another hereafter. The presence of muriatic acid is essential to their existence, the nitrate of cobalt producing no such phenomenon ; nor did I find that the presence or absence of light had any effect in retarding or promoting any of the changes of colour here mentioned.

The nitrate of nickle applied to cotton impregnated with soda and sugar, produced a green, but not sufficiently durable to be of any use in this way.

Nitrate of manganese by some of these impregnations produced different browns, which seemed to possess considerable permanency.

I could add the results of several other applications of this sort, but at best they would only prove to be what Bacon Lord Verulum has termed *Experiments of light rather than of fruit*; and indeed this may be the case with many of those which I have just related. It would not, however, be the case of those which regard the application of gold as a substantive colour, if the dearth of that metal were not an obstacle to its use in this way; since the beauty of its purples and violets, and the facility of applying them topically and permanently by the pencil to fine muslins, silks, &c. would otherwise render them very desirable and ornamental. It is doubtless on principles similar to those before mentioned, that some compositions which afford very durable black colours for marking on linen, &c. are now made and sold in London. Soda, dissolved and thickened by a little isinglass, or some animal mucilage or glutinous matter, is probably first applied, and, when dried, names or letters are written thereon, with a pen dipped in particular metallic solutions.

In the first Volume of *Ann. de Chymie*, Mr. Berthollet observes, that the simple mixture of oxide of lead with lime, blackens wool, hair, nails of animals, and white of egg, but not silk, nor skin, nor the yolk of egg, nor animal oil; and that some persons use this mixture to render white or grey hairs black, first slackening the lime. To try

try its effects in dying, I boiled flannel in lime-water with litharge, and found that it took a pretty full black, which stood washing with soap and exposure to the weather. Strong acids dissolved the lead, and changed the colour; but the application of vinegar did not seem to do so. The lime, however, weakened the texture of the wool considerably, as he has also observed. Whether this evil can be avoided by using it more sparingly, I have not yet ascertained. I found the mischief greatly increased by adding orpiment, which seems to produce a similar effect in those depilatory compositions first brought to Europe from Turkey.

CHAP. VII.

Of Adjective Colours generally.

“ Les faits sont de tous les temps, ils sont immuables,
 “ comme la nature dont ils sont le langage; mais
 “ les conséquences doivent varier selon l'état des
 “ connoissances acquises.”

CHAPTAL *Elémens de Chimie.*

ALL adjective colours owe their durability, and frequently their particular complexions, as well as their lustre, to the interposition of some earthy or metallic basis; which, having a considerable attraction both for the colouring matter, and the fibres of the stuff about to be dyed, combines with and serves as a bond of union between them. These earthy and metallic substances, having been usually employed

in a state of solution or combination with acids, were from that circumstance denominated *mordants* (biters or corrodors) by the French, who indeed began to employ the term long before any thing like a true theory of dying had been conceived; whilst even allum was supposed to act by its sulphuric acid, and not by the pure clay upon which its usefulness depends, and whilst in truth all the other matters called mordants were supposed to be useful only by their solvent or corroding powers; and the term having been thus introduced, has been since adopted in other countries. The ingenious Mr. Henry of Manchester has, however, lately objected to it, with great reason*, and proposed in its stead to employ the term *basis*, a term which seems defective only in as much as it does not express that particular *affinity*, or *power of attraction*, which manifestly subsists between these earthy and metallic substances, and the several adjective colouring matters, as well as between the former and the fibres of wool, silk, cotton, &c. I confess, however, that no other less objectionable term has occurred to me; and being unwilling to propose new terms, without some cogent reason, I shall employ both the term of mordant and that of basis; though not indiscriminately, in all cases at least, since I shall generally use the former to signify these earthy and metallic substances, when actually dissolved by some acid, alkaline, or other solvent, and when of course they will commonly prove more

* See his "Considerations relative to the Nature of Wool, Silk, and Cotton, as Objects of the Art of Dying, &c." in the third Vol. of the Memoirs of the Manchester Society.

or less corroding or biting, according to the original meaning of the term. But the denomination of bases will most frequently be employed to designate the same earthy and metallic substances, distinctly and separately from any acid or other solvent, either in relation to their properties, when actually fixed in the pores or fibres of wool, silk, &c. or when it is not intended to notice any property which may more immediately result from their combinations with any particular menstruum. Mr. Berthollet indeed gives the term mordant a much more extensive signification, as meaning all the different chymical agents capable of serving as *intermedia*, between the several colouring particles, and the stuffs to be dyed with them, either for the purpose of assisting their union, or of modifying it*. This last effect (of modification) may, however, be produced by a variety of matters besides those which are of the earthy or metallic kinds, and indeed by every thing capable, not of fixing, but of varying only, the shades of adjective colouring matters. These, therefore, I think it more proper to designate, not as mordants or bases, but as *alterants*, whose use and application may in this respect be extended to substantive as well as to adjective colours.

The true natures and uses of mordants or bases for the purposes under consideration, can,

* “ L’on donne le nom de mordant aux substances qui
“ servent d’intermedes entre les parties colorantes & les
“ etoffes que l’onteint soit pour faciliter leur combinaison,
“ soit pour la modifier.” *Elemens de l’Art de la Teinture*,
tom. i, p. 26.

I believe, in no way be so distinctly manifested, or so clearly illustrated, as by their effects in what I shall call *topical* dying, or that species of it by which different colours are communicated to particular spots or figures, on the same piece of cotton or linen, according to the several bases previously applied thereto, and which principally constitutes that truly wonderful art, the art of callico-printing. I shall therefore in this place bring under my reader's notice some of the more important operations of that art, reverting at the same time, as far as we can, towards its remote origin, in order to see how and by what means it has attained its most important improvements.

Pliny describes the Egyptians as practising a species of topical dying, or callico-printing, which, as far as can be discovered from his general terms, appears to have been similar to that which, many ages after, was found to exist in Hindostan and other parts of India, and was from thence introduced into this and other countries of Europe. He says, the Egyptians began by painting or drawing on white cloths, (doubtless linen or cotton,) with certain drugs, which in themselves possessed no colour, but had the property of attracting or absorbing colouring matters. After which, these cloths were immersed in a heated dying liquor, and though they were colourless before, and though this dying liquor was of one uniform colour, yet when taken out of it soon after, they were found to be wonderfully tinged of different colours, according to the different natures of the several
drugs

drugs which had been applied to their different parts; that these colours could not be afterwards discharged by washing, &c.*

Whether the Egyptians borrowed this wonderful art from the Hindoos and other inhabitants of India, or whether the latter borrowed it from the Egyptians, is a question which probably may be answered without much difficulty, if we consider the many reasons which there are for believing that this art has been practised over the greatest part of India during a long succession of ages; that not only the art itself subsisted there, but that the colouring, and other materials for exercising it, were the natural and peculiar productions of that country rather than of Egypt; that the Indians were highly civilized at least twenty-two centuries ago, during which space of time their manners, sanctified (if I may so express myself) by being connected to their religion, suffered little, perhaps no change; and their trades were carefully perpetuated in particular families; and also that among these their manufactures were undoubtedly of very great antiquity, whilst obvious ways, by which they

* “ *Pingunt et vestes Ægypto inter pauca mirabili genere, candida vela postquam attrivere illinentes non coloribus, sed colorem sorbentibus medicamentis. Hoc cum fecere non apparet in velis sed in cortinem pigmenti ferventis merfa, post momentum extrahuntur picta. Mirumque cum sit unus in cortina colos, ex illo alius atque alius sit in veste accipientis medicamenti qualitate mutatus. Nec postea ablui potest. Ita cortina non dubia confusura colores si pictos acciperet, digeret ex uno, pingitque dum coquit. Et adustæ vestes firmiores fiunt quam si non urerentur.*” PLINII, l. xxxv. sect. 42. fol. 789.

might

might-have been easily extended to Egypt, and other countries, undoubtedly existed long before the time when Pliny wrote.

Major Rennell observes, that “ a passion for
 “ Indian manufactures and products has actuated
 “ the people of every age, in lower Asia, as well
 “ as in the civilized parts of Europe: The delicate and unrivalled, as well as the coarser and
 “ more useful fabrics of cotton of that country
 “ particularly suiting the inhabitants of the temperate regions along the Mediterranean and
 “ Euxine seas. To this trade (continues he)
 “ the Persian and Arabian Gulfs opened an easy
 “ passage; the latter particularly, as the land
 “ carriage between the Red Sea and the Nile,
 “ and between the Red Sea and the Mediterranean, took up only a few days. It is highly
 “ probable, and *tradition in India* warrants the
 “ belief of it, that there was from time immemorial an intercourse between Egypt and Hindostan, at least the maritime part of it; similarity of customs in many instances, as related
 “ of the ancient Egyptians by Herodotus, (and
 “ which can hardly be referred to physical causes,)
 “ existing in the two countries.”—“ It would
 “ appear, that under the Ptolemies the Egyptians extended their navigation to the extreme
 “ point of the Indian Continent, and even sailed
 “ up the Ganges to Palibothra.” See Memoir and Map of Hindostan, &c. 4to. by James Rennel, F. R. S.

The first, and perhaps the only good accounts of the practice of callico-printing in the East-Indies, were given in certain letters, written by
 Father

Father *Cœurdoux*, a missionary at Pondicherry, (published in the xxvith Volume of "Recueil des Lettres Curieuses & Edifiantes, &c.") with the Supplemental Remarks and Corrections of the celebrated *Monf. Poivre*; and in a Manuscript Account procured from thence by *Monf. du Fay*, and communicated to the Royal Academy of Sciences at Paris, by the *Abbé Mazeas*.—By these accounts it appears, that the cotton cloths, when brought from the weavers, partly bleached, were worn next to the skin, by the dyer and all his family, during the space of eight or ten days; after which they underwent several macerations in water with goats' dung, accompanied with frequent intermediate beatings, washings, and dryings, in the sunshine. Afterwards they were soaked for some time in a mixture of the mucilaginous astringent fruit of the yellow Myrobalans, *Myrobalanus Citrina* of Ray, (called "Cadoucaie,") well bruised, and of curdled buffaloes milk; and being thoroughly penetrated and impregnated therewith, they were taken out, and the liquor being well squeezed from them, were dried by exposure to sunshine, and afterwards, by pressure and friction, made smooth enough for being drawn upon by the pencil, with the different mordants. The first of these was an iron liquor (acetite of iron), similar to that since employed by the callico-printers of Europe, excepting only that, instead of vinegar or alegar, the iron was dissolved by a mixture of four palm wine, and of water in which rice had been boiled. This liquor was applied to the figures or spots intended to become black, and afterwards the aluminous mordant was applied, commonly by children, with the

the pencil, to the parts intended to be made red. To prepare this mordant, two ounces of allum were dissolved in two quarts of water, taken from certain pits, wherein it was supposed to be better for this use than common water, though it was found on examination to have no particular taste, and thirty ounces of it being evaporated, left only a residuum of eleven grains of sea salt. To colour this solution, so that the strokes of the pencil in applying it might be visible, a little sappan or sampfan wood (*Cœsalpinia Sappan*, of Lin.) in powder was steeped in the solution, which being afterwards strained, was thickened with gum, and applied as before mentioned; after which the cotton so penciled was exposed to the hottest sunshine, in order that the parts to which the mordants had been applied might be dried as much as possible; and then the cottons were thoroughly soaked in large pits of water, to cleanse them from the loose superfluous parts of the different mordants, as well as from the buffalo's milk, &c.; and this being done, they were dyed in water, with certain roots answering nearly in their effects to those of madder. Of these there are several sorts used for dying red in different parts of India, which will be more particularly mentioned hereafter; that pointed out by the accounts in question, is described as a species of gallium, called on the coasts of Coromandel and Malabar by the names of Chaia, Chayaver, and Raye de Chaye. The cottons penciled, &c. as before mentioned, and gradually made to boil in water with a suitable quantity of this root, were dyed *red*, where the solution of allum had been applied, and black in those parts on which the iron liquor had been pencilled;

pencilled ; and after being dyed, the cottons underwent three different washings with goats' dung, soap, &c. were then bleached by being exposed to the sun, and watered occasionally, to remove the stain on the parts intended to remain white.

It appears, that in this operation the buffalo's milk, and more especially the astringent juice of the Myrobalans, produced very important effects, by their attraction for the aluminous earth, by which they contributed greatly to decompose or separate it from the sulphuric acid, and consequently to fix it more firmly in the cotton ; and being so fixed, it was enabled more strongly to attract and retain the colouring matter of the Chaia root whilst in the dying vessel, and thereby to produce a more permanent red in the different spots, figures, or designs where the allum liquor had been applied. A mixture of this and of the iron liquor, acting and applied in the ways before mentioned, produced also a durable purple in the same dying vessel, upon the parts impregnated therewith ; and consequently one dying with the colouring matter of a single root, produced at the same time reds, purples, and blacks.

The East-Indian method of dying blue from indigo, (a substantive colour,) by covering over with wax the several parts intended to be reserved white, does not fall within our present inquiry. Neither is the yellow colour employed for callico-printing in that country deserving of much notice, it being composed only of a decoction of *cadoucaipou*, a species of galls, produced

duced on the yellow Myrobalan tree, (which give a dull yellow,) and of a suitable portion of allum, which being thickened with gum, and penciled over blue figures or designs, produces a green, and on white parts or grounds, a yellow colour; neither of which is however sufficiently durable. But in this composition we have an adjective colour directly combined, and topically applied with its basis, instead of being applied separately, as is most usual.

Such compositions (which will be frequently under consideration hereafter) assume the form of substantive colours, without being such in reality; and as it may be useful to distinguish them by an appropriated term, I beg leave in future to call them *pro-substantive topical colours*, wherever an adjective colour, and its basis or mordant, are thus mixed and applied together *topically*, either by the pencil or the block.

The art of callico-printing, since its introduction to Europe, has been divested of many tedious operations and manipulations, which indeed would have proved insupportably expensive here, on account of the higher price of labour, and of almost every thing necessary to human subsistence. But the greatest European improvement in this art respects the aluminous mordant, and depends on the employment of sugar of lead (acetite of lead), or the oxyd of that metal dissolved by distilled vinegar, and crystallized; which within the memory of man has been gradually brought into use, without any theory or even suspicion of its true effect, or of the way in which it proved so highly useful.

ful. This improved aluminous mordant is now generally made by dissolving three pounds of alum in a gallon of hot water; then adding one pound, or in some particular cases one pound and a half, of the acetite or sugar of lead, stirring the mixture well during two or three days, and afterwards adding to it about two ounces of pot-ash, and as many of clean powdered chalk (carbonate of lime). In this mixture, both the alum and the sugar of lead are decomposed by a double elective attraction, which produces two new compounds, according to Mr. Henry and Mr. Berthollet, because the oxyd of lead having a stronger attraction for the sulphuric acid than for that of the vinegar, combines with the former, and producing an insoluble salt, subsides to the bottom of the liquor, whilst the earth of alum, thus left in a very divided state, unites to, and is dissolved by the acetous acid, previously separated from the lead, and remaining in the liquor, which thereby becomes a diluted acetite of alumine; the pot-ash and chalk only serving to neutralize the excess of sulphuric acid, which is always contained in alum, and which would in some degree hinder the alumine from being deposited and fixed in the fibres of linen and cotton. But the decomposition here described takes place only *in part*, because one pound of sugar of lead, or even one and a half, (the greatest quantity any where proposed,) is not sufficient to decompose three pounds of alum. On the contrary, I have found that alum cannot be completely decomposed, without two-thirds at least of its weight of sugar of lead; and where less has been used, I have always been able, by evaporation, to detect a quantity of it

in the aluminous mordant. I shall have occasion hereafter to revert to this subject, and shall therefore content myself at present with remarking, that the printers' aluminous mordant is not in fact a mere solution of the alumine, or earth of alum, by the acid of vinegar, as those eminent chymists Mr. Henry and Mr. Berthollet suppose, but that even with the greatest proportion of sugar of lead ever employed by the calico-printers, it contains a considerable portion of alum in its original state; I mean that in which the argillaceous earth or alumine is combined with sulphuric acid. Notwithstanding this circumstance, however, I shall generally consider this preparation as being in reality what it is not strictly, an acetite of alumine, and shall commonly distinguish it either by that name, or by that of the printers' aluminous mordant.

The mixture or mordant in question being thus made, and the clear liquor decanted from the sediment, it is afterwards thickened with flour, if intended to be printed or applied by the block, and with the gum of the *Mimosa Nilotica* (Gum Arabic), or of the *Mimosa Senegal* (Gum of Senegal), if it be intended for penciling; and being applied in either of these ways to linens or cottons, it is afterwards very thoroughly dried in a room artificially heated, and then the pieces of linen or cotton, so printed or pencilled with the mordant in question, are cleansed as perfectly as possible, by soaking and working them in a cistern with warm water and cow-dung, and afterwards rinsing them in clean water to dissolve the gum or flour, and separate

the superfluous or loose parts of the mordant, which otherwise would in the dying vessel combine with the colouring matter, and greatly stain the grounds, or parts intended to be preserved white. This will indeed unavoidably happen in some degree, notwithstanding the most perfect cleansing. But as the colouring matter which these grounds or parts absorb from the dying liquor will not, when the cloths have been thoroughly cleansed, be retained or fixed by any basis, they are speedily whitened, by being boiled in water with bran, exposed upon the grass, and by other means well known.

By thus substituting the acetous for the sulphuric acid in the aluminous mordant lately described, several considerable advantages are gained. The acetite of alumine being much more soluble in water than common alum, the liquor will contain a much larger proportion of alumine than could be otherwise suspended in it; and with this advantage moreover, that it will not be liable to form crystals in or upon the linens or cottons in drying, as would happen with a solution of common alum, the acetite of alumine being incapable of crystallization. I may add also, that the acid of vinegar being volatile, and having a much weaker attraction for its earthy basis than the sulphuric acid has, the former will be speedily separated and carried off, especially by the heat of the stoves employed for drying the pieces printed with it, and will leave behind the alumine which it had held in a state of solution, and which being no longer encumbered by any other attraction, will yield itself wholly to that which subsists between it

and the fibres of linen or cotton, and will unite with them more copiously and firmly than it otherwise could do, and be thereby enabled more strongly to attract and fix the colouring matters in the dying vessel. This, however, will only prove true, so far as the sulphat of alum has been really decomposed by the acetite of lead, or so far as the alumine has been combined with the acetous instead of the sulphuric acid.

As the practice of calico-printing has been but lately introduced into Europe, and as the acetated aluminous mordant does not appear to have been previously known in any other country, we might have expected that its discovery in this would have been deemed a matter so important, as to have constituted an era in the history of the art; and therefore I was not a little surprised in finding that no writer had mentioned, and that no calico-printer of whom I have inquired could inform me, at what time, or by whom this mordant was first employed, as the basis of red and yellow colours in calico-printing. My wonder has, however, ceased on this subject, since I have inspected a considerable number of recipes for making the several mixtures employed as mordants, soon after the business of calico-printing began to be carried on with some degree of success here and in other parts of Europe. In one of these, which seems to have been the earliest, alum, sal ammoniac, saltpetre, red orpiment, and kelp, were directed to be mixed with water. In another, which probably followed this, it was directed that these ingredients should be dissolved in vinegar. In a succeeding

succeeding recipe, a little sugar of lead was directed to be employed, but in a quantity too small to be of any considerable use; I mean one ounce of it for every pound of alum. Afterwards the calico-printers, without any system or reasonable motive, appear in different instances to have added verdigrise, arsenic, corrosive sublimate, blue vitriol, *litbarge*, and *white lead*. By stumbling upon the two last (which alone were of any use), it happened, where vinegar had been also employed, as it commonly was in some shape, that after a variety of decompositions and recompositions, some portion of acetite of alumine was formed, the good effects of which were experienced, though without any true knowledge of the ways and means by which they had been produced. By degrees, however, the printers seem to have increased the quantity of sugar of lead, and several of them to have suspected that many of the other ingredients usually employed for making their mordants were useless. Some of them, therefore, began to omit one, and some another of these ingredients, until at length all the useless ones were laid aside, though without the aid of any chymical reasoning on the subject, and without any one ever suspecting, as indeed few of them do at this day, that the lead which they continued to employ occasioned any decomposition of the alum, or that the mordant so produced did not really contain all the ingredients used in preparing it. Among the useless ingredients before mentioned, corrosive sublimate seems to have been retained the longest, since Mr. Wilson includes it in his recipe, which was

published so lately as the year 1786. (See his Essay on Light and Colours, &c.)

It is not wonderful, therefore, that no particular person or period has been noted, or remembered as distinguishable for the first invention of the acetated aluminous mordant; since the sugar of lead, or other means of forming it, were at first used by chance so sparingly, as to have scarcely produced any better effect than would have resulted from the mere solution of alum, and the alterations and improvements by which the mordant afterwards acquired its present form, I had almost said perfection, were made by such imperceptible gradations, and resulted so much from the random additions and omissions of different individuals, (no one of whom seems to have been guided by any thing approaching to a just theory,) that neither the discovery, nor any considerable step towards it, can properly be referred to any one person or period.

Mr. Henry, justly sensible of the superior advantages of the acetated aluminous mordant in calico-printing, and conceiving it to have really been very anciently known and employed in those countries where the art was first practised, concludes from thence, that it must have resulted from a very advanced state of chymical knowledge in those countries at some very remote period, which was afterwards lost, whilst the improvements arising from it in this respect, continued to be practised and handed down, through a long succession of ages to the present time.

time. "To have invented (says he) the process of printing, in the manner described by Pliny, the inhabitants of India must probably have known how to prepare alum; they must have been acquainted with the manner of dissolving lead in the vegetable acid; they must at least have been acquainted with the component parts of these salts, and they must have had a knowledge of double elective attractions, &c." In truth, however, the inhabitants of India neither had, nor have they at present, any knowledge of the use of sugar of lead, or of any other preparation of that metal which could produce similar effects in calico-printing; a solution of common alum in water being their only aluminous mordant, and the previous application of the soluble parts of mirobals to their calicoes, aided by a very hot sunshine, enabling them, without any thing like an acetite of alumine, to produce effects nearly equal to it. This fact I have learned not only from all the accounts published or transmitted to Europe respecting this point, but from the positive verbal informations of eye-witnesses to the practice of calico-printing in that part of the world, and particularly of a gentleman of great veracity, as well as knowledge on this subject, who formerly carried on the business of calico-printing very extensively in Bengal (principally for account of the East-India Company): and indeed sugar of lead is so far from being used for this purpose there, that within a few weeks I have received a letter from Mr. John Adie, (successor to the gentleman last mentioned,) dated, "Gondelpara, near Chandernagore, the 10th of February 1792," and mentioning, that

he had some little time before been obliged to pay twenty shillings the pound for sugar of lead, in order to prepare a particular colour which I had formerly recommended; so far was this ingredient from being in use there for any such purpose.

We may therefore safely conclude, that the formation of an acetite of alumine, and its application as a mordant in calico-printing, was not an oriental discovery; and that it did not result from any knowledge of double elective attractions, or any other extensive chymical knowledge either in ancient or modern times; since those who gradually stumbled upon and introduced the use of it, were totally ignorant of the decompositions and recompositions which took place in their mixtures, and always supposed, as all other calico-printers have till lately done, and as most of them now do, that the aluminous mordant really consisted of every thing used in producing it.

To illustrate more plainly the differences of colouring matter, as well as the action of an aluminous basis upon them, let us examine its effects in a few particular instances: taking a bit of cotton upon which certain figures and designs had been printed, with the acetated aluminous mordant, and which, after being dried, had been cleansed in the usual way, I dyed it in water with saffron; the water readily extracted the yellow colour of the saffron, and the cotton soon imbibed so much of the colour as to become equally yellow in all its parts, without the least appearance even of a difference
of

of shade where the alumine had been applied. The cotton so coloured being exposed to air, soon became equally and uniformly white; the colouring matter of the saffron having no particular affinity to the alumine: to see, however, whether this last remained fixed in the fibres of the cotton, I dyed the same bit, which the saffron colour had thus abandoned, in water with a little Brazil wood, and the figures, where the alumine had been applied, became of a strong, full, and most beautiful crimson; the other parts, to which no basis had been applied, being but slightly discoloured. The cotton so dyed being exposed to the sun and air two or three days, the spaces to which no mordant had been applied became perfectly white; the figures, impregnated with alumine, had lost some of their fine crimson colour, and this gradually diminishing, was all gone at the end of eight days. Here then we see, that the aluminous basis had a certain affinity with the colouring matter of the Brazil wood, (which was not the case with that of saffron,) but not so much as to fix and retain it permanently. To see however that this was really the case, and that the defect arose from the want of a sufficient affinity between the colouring matter and the alumine, and not between this last and the cotton, I took the same bit which had been already twice dyed, and dyed it a third time in water with madder, whereby the whole bit became coloured, but the figures impregnated with alumine much more deeply than the other parts; a proof that the alumine still remained fixed, notwithstanding the escape of the Brazil wood crimson, and that it had again entered

entered into a triple combination with the madder colour, and the fibres of the cotton. The bit so dyed, being well boiled in water with bran and exposed to sunshine and air, in a few days became white in the parts where no mordant had been applied to fix and retain the colour, whilst the figures formed by the application of alumine retained all their body and brightness; the colouring matter of the madder, in this triple combination, not being liable to destruction or separation by the same means which destroyed or separated it where no such bond of union or means of preservation existed.

It has been already noticed, that in oriental calico-printing the solution of alum is coloured red with sampfan or sappan wood; and I might have added, that in dying with roots analogous to those of madder, the red colour of the wood is dislodged from the pores of cotton by the superior attraction of the root colour, which takes its place. Neither the East Indians, however, nor the writers who have given accounts of their operations, seem to have been apprised of this fact; but concluded that the red wood colour was fixed and made durable by the application of that of the roots. To ascertain the truth on this point, I dyed a bit of cotton impregnated with acetate of alumine like that last mentioned, with Brazil wood, and the figures impregnated with the mordant became as before of a fine crimson colour. I then rinsed the dyed cotton, and putting it into another vessel with clean water, added gradually so much decoction of madder as was sufficient for that weight of cotton,

cotton, and dying it in the usual way, I found that I had a madder red instead of the fine Brazil wood crimson. The colouring matter of madder having decomposed and dislodged the Brazil wood colour, with which the water was visibly tinged, and which being divided into several parts, and tried by different chymical agents, underwent all the changes which are usual to the colouring matter of Brazil wood, and not those which happen in the like circumstances to the colour of madder. The bit of cotton, to which the madder colour had applied itself by dislodging that of the Brazil, being also tried in various ways, manifested the durability and other appearances usual to madder colours.

If cottons printed with the acetated aluminous liquor, as before-mentioned, be dyed with Weld or Quercitron bark instead of madder, this basis will attract their colouring particles in the same manner, and produce permanent yellows upon the figures where the alumine was previously fixed; the other parts being but slightly tinged, and being afterwards easily bleached or whitened, because there is no mordant to hinder the separation or destruction of the colouring matter of these dying drugs. The dying of yellows, however, in this way, is an European invention; the people of India having only given them, as already mentioned, by a *pro-substantive* mixture of the decoction of the galls of mirobalans with alum. And indeed this practice was followed here for some time after the introduction of the art into Europe, excepting that instead of the galls of the mirobalan tree,

a de-

a decoction of French berries (*Rhamnus infectorius*, Lin.) was employed; by which, indeed, a very full bright yellow was at first communicated, but of so *fugitive a nature*, that the use of these berries, which in some degree still subsists, ought to be prohibited; it being impossible, by any means yet known, to obtain from them a colour fit for any other purpose than that of deception. If instead of the aluminous basis, cottons or linens be impregnated with iron liquor (acetite of iron) of different degrees of strength, and dyed with madder, they will receive permanent dark browns of different shades, and even a full black: and if instead of iron liquor alone, it be mixed in different proportions with the acetite of alumine, the mixture will produce with madder all the shades of flea-colour, purple, violet, &c.

But when, instead of madder, cottons or linens are printed with iron liquor, and dyed with weld (*Reseda Luteola*, Lin.) or Quercitron bark, (*Quercus nigra*, Lin.) they receive a variety of olive-brown, drab, and dove colours; and if instead of iron liquor alone, a mixture of it, with acetite of alumine, be used as a mordant, they will take various shades of olive, olive-green, &c. And, indeed, by the help of these two mordants only, (from iron and alumine,) used separately, as well as mixed in various proportions, and afterwards combined with the colouring matters of madder and of weld, or (instead of the latter) of Quercitron bark, aided by the blue from indigo, nearly all the possible varieties and shades of colour are now given in the way of calico-printing.

Hitherto

Hitherto the art of calico-printing has been confined almost solely to linens and cottons, which are suited to it, by being susceptible of a permanent union with colouring matters, and especially with their bases, by only the common warmth of the atmosphere: and as this is also the case of silk, there can be no doubt but this last might be made the subject of new and beautiful embellishments in that way, which, if properly executed, would undoubtedly become a source of gratification to the public, and of profit to individuals.

Very lately indeed a species of topical dying or staining, very much resembling some parts of calico-printing, has been ingeniously applied to woollen stuffs, and particularly those called kerseymeres, for waistcoat patterns, &c. What I mentioned in a former chapter, of the necessity of a considerable degree of heat, to enable the fibres of wool to receive and combine with colouring matters, will afford some idea of the difficulty of applying and fixing different colours in the form of spots or figures upon woollen stuffs in this way by dying; the particular mode and means by which this difficulty is overcome, and the several colours fixed in the fibres of wool, are still kept secret as much as possible. How proper colours for this purpose may be provided, either from substantive colouring matters, or from the adjective ones, made into the form of a strong decoction, and mixed with the proper mordants, (as in the instance which I lately noticed of a pro-substantive yellow,) will be easily understood by those who may attend to what has been,

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or will be explained in the course of this work; and such colours being so prepared, and printed upon kerseymere, &c. in the usual ways, may be, as I have found on trial, and as I am informed they are, made to penetrate and unite with the wool, by placing the stuff so printed in the steam of boiling water for a sufficient length of time, first wrapping it up in thick paper, doubled or trebled, so as to exclude the moisture, so far at least that it may not occasion the colours to run beyond their proper limits.

After this summary account of the origin, progress, and nature of calico-printing, intended to illustrate more distinctly the effects of the principal bases or mordants, it will be proper here to take a general view of the facts which respect the application of these bases, for fixing and modifying different adjective colours, not by topical, but by general dying, as well upon wool and silk, as on linen and cotton.

The two last of these are made fit for the application of a basis, by being boiled for the space of two or three hours in a solution or ley of pot-ash of suitable strength; then spread for some time on the bleaching ground; afterwards soaked in water, made sour by the addition of one-fiftieth or sixtieth of its weight of sulphuric acid or oil of vitriol, and finally rinsed thoroughly in clean water, and dried. When thus prepared, if the aluminous basis is intended to be applied to them, perhaps there is no form in which it could be more effectual than that of the acetated aluminous mordant, though motives of œconomy have always induced the mere dyers of
linen

linen and cotton to employ cheaper preparations of alum. The sulphate of alumine, or common alum, will indeed yield a considerable part of its earthy basis to linen and cotton, when dissolved by water and applied to them; but it does this more readily when deprived of its excess of acid by pot-ash or calcareous earth; and it is in this way commonly employed as a mordant for linens and cottons. About four ounces of alum, with water sufficient to dissolve it, and half an ounce or somewhat less of pot-ash, being generally allowed for each pound of linen or cotton intended to be dyed, which is to be macerated, &c. in this liquor until thoroughly and equally penetrated by it, and afterwards well rinsed to separate the superfluous or loosely adhering alum, &c. Cotton treated in this way commonly gains about two and a half per cent. additional weight, by the earth of alum which combines with it. But where no white grounds are to be reserved, there are ways of rendering the aluminous basis more effectual, and particularly for madder colours upon linens and cottons, by impregnating them at the same time with oleaginous, resinous, glutinous, and alkaline substances, which occasion an increased affinity or attraction between the fibres of the linen and cotton, as well as between these and the colouring matters, thereby forming perhaps a kind of cement, which renders them more fixed, and less liable to be acted upon and injured by those causes which generally destroy or weaken colours.—These auxiliary means will hereafter be noticed in their proper places.

Silk

Silk is impregnated with the aluminous basis by macerating or soaking it only during the space of ten or twelve hours in a saturated cold solution of alum, afterwards rinsing it, &c.

To impregnate wool with the aluminous basis, it is commonly boiled in water with about one-sixth or one-eighth of alum, and about half as much tartar. The heat is gradually raised to the boiling point, and the liquor kept boiling for about an hour; then taken out, drained, and left until the next day, when it is well rinsed. Wool, from its animal nature, has a much stronger attraction for alumine than either silk, linen, or cotton, but will not decompose a solution of alum without the aid of a considerable degree of heat. Tartar, as Mr. Berthollet observes, seems principally useful in this way, by moderating the strong action of alum upon the fibres of the wool, and preventing too great a deposition of the aluminous earth in their pores, which would render the fibres apparently coarser. Perhaps, however, a more sparing use of alum might in some degree obviate the necessity of using tartar for this purpose; and some dyers have lately omitted the use of it in many cases where it was formerly always employed, particularly in the boiling preparation for weld yellows. Tartar has, however, other considerable effects in modifying and varying the shades of colours, as will be seen hereafter.

For the dying of wool and silk, the basis of iron is usually employed subsequently to the colouring matter which it is intended to fix and modify,

modify, or interchangeably with it; and in these ways copperas (sulphate of iron) is most frequently used. Alumine and iron in some form or other were very anciently employed as mordants in dying; and indeed they seem for many ages to have been the only substances used as such, which is at present nearly the case in calico-printing. Mr. Hauffman, in a letter very lately written to Mr. Berthollet, (see *Ann. de Chymie*, tom. vii.) maintains, "that of all acid, alkaline, earthy, and metallic substances, there is, strictly speaking, none, excepting the oxyd of iron and alumine, which possess the property of attracting the colouring particles of drugs proper for dying, such as madder, weld, logwood, &c. which separately or combined, and differently modified, are capable of producing with these substances an infinite variety of colours, and shades of colour, more or less durable." Here, however, Mr. Hauffman is misled, by confiding in his own experience as a calico-printer only; for in dying, it is notorious that the oxyds or solutions of several of the metals besides iron, and particularly those of tin, copper, and zinc, are used to fix colours, in consequence of the attractions which they exercise upon the colouring particles of different dying drugs; and it will be hereafter proved, by my own particular experiments, that there is none of the metals or semi-metals, nor any even of the different earths, which does not in some state and degree at least possess a power, not only of modifying colours, but of attracting and fixing colouring particles more or less

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strongly in the way of dying; though it must be confessed, that of the several earths, none is in this respect so powerful and so useful as the alumine; indeed this and the oxyd of tin seem to be the only bases suited by their perfect whiteness to reflect the rays of light, so as to exhibit the natural colours of the different adjective dyes with full lustre; every other basis hitherto known having been found in most, if not in all cases, to darken or sadden, perhaps I might say degrade, the natural colours of these dyes, at least in some degree. Probably zinc does this less than any other metallic basis, excepting tin, which indeed, with a very few exceptions, reflects the rays of light more copiously, and exhibits colours more brilliantly than alumine, because its oxyd unites with colouring matters as a basis, in a much larger proportion than the alumine will do. Perhaps also the particles of this oxyd are more perfectly white than those of alumine. In most cases, however, the attraction which a metallic basis exerts upon an adjective colour in dying, is not simply the result of its own affinity with the particles of that colour, but of its own affinity combined with the affinity of the stuff imbibing the dye. Thus in the dying of scarlet, it is every day seen that pieces of woollen cloth or stuff, having at each edge a narrow longitudinal stripe, formed by an intermixture of cotton yarn, after being impregnated in the usual way with the mordant or oxyd of tin, will attract and imbibe the colouring particles of cochineal, so as to exhaust the dying liquor, and sometimes leave it perfectly colourless, and become scarlet in every part, excepting

excepting the stripes formed of cotton-yarn, which always come out of the dying liquor without the smallest tinge or change of colour, though both the mordant and the particles of cochineal are applied to the latter equally with the other parts of the cloth. Here then either the oxyd will not combine with the fibres of cotton, whilst it is subject to a stronger attraction from the woollen part of the cloth; or if it does combine with the fibres of cotton, their joint attractive power is so much weaker than that which the oxyd of tin and the wool united exert upon the cochineal, that they are unable to draw and fix any part of the colouring matter to or in the cotton, so long as this colouring matter is liable to the prevailing attraction of the wool and oxyd of tin united; and that this latter is really the case, will appear by experiments to be mentioned hereafter.

Mr. Berthollet, as will be remembered, considers not only the decays of colours, but their production in many cases as the result of some degree of combustion; and upon this principle he maintains, "that the colour which the compounds of metallic oxyds and of colouring particles assume, are the product of the colour peculiar to the colouring particles, and also of that which is peculiar to the metallic oxyd; but, adds he, the colouring particles and metallic oxyds must be considered as in that state to which they have been reduced by the diminution of oxygene in the oxyd, and of hydrogen in the colouring particles." Hence (continues Mr. B.) metallic oxyds, to which the oxygene is but slightly attached, are

“ not fit to serve as connecting media for the
“ colouring particles, because they produce in
“ the latter too great a degree of combustion;
“ such are the oxyds of silver, gold, and mer-
“ cury.” “ That oxyds which undergo con-
“ siderable changes of colour, by giving off
“ more or less of their oxygene, are also bad
“ intermedia, especially for light shades, be-
“ cause they produce changeable colours; such
“ are the oxyds of copper, lead, and bismuth.”
“ That the oxyds which strongly retain their
“ oxygene, and suffer but little change of co-
“ lour by losing a part of it, are best fitted to
“ answer this purpose; such, says he, is parti-
“ cularly the oxyd of tin, which quits its men-
“ struum easily, has a strong attraction for co-
“ colouring particles, and affords them a basis
“ very bright and very proper to reflect their
“ colours with lustre, unaltered by the admix-
“ ture of any other shade of colour. The
“ oxyd of zinc possesses some of these proper-
“ ties.”

“ We must then distinguish, (adds he,) in the
“ action of mordants, the combinations that may
“ take place by their means between the colour-
“ ing particles, the stuff, and the intermediate
“ basis; the proportions of this latter, and of the
“ colouring substance; the modifications of co-
“ lour which may arise from the mixture of the
“ colour of the colouring particles, and of that
“ of the basis to which they are united; and
“ finally, the changes which the colouring par-
“ ticles may suffer from the *combustion* produced
“ by the intermediate basis.”

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I have already noticed some facts which induced me to distrust that part of Mr. Berthollet's theory, which supposes the decays of colours to depend upon combustion, at least in many cases; and there are some which appear equally strong against that part of it which ascribes their production to a like effect. Upon this subject, however, I will at present only observe, that in many cases both alumine and metallic oxyds, when dissolved by pot-ash, soda, and ammoniac, produce, with particular dying drugs, colours exactly similar to those, which the same bases, dissolved by nitric acid, produce with the same drugs; though in the former case it is difficult to conceive how the metallic oxyd, and especially the alumine, should furnish oxygene to produce the supposed combustion; whilst in the latter these different bases, by having been combined with nitric acid, certainly might furnish the means of combustion; and ought therefore, upon Mr. Berthollet's supposition, to produce darker colours than those which result from the same bases, united with volatile alkali, soda, and pot-ash.

It seems therefore most probable, that when the oxyds of metals alter the natural colours of dying drugs, the new colours thus produced are the specific results of the particular combinations between such oxyds and the drugs united to them, independently of any effect strictly deserving the name of combustion.

Having thus generally explained and illustrated the properties and uses of mordants on bases, in fixing and modifying adjective colours

by dying, I shall proceed to a particular inquiry concerning their effects upon each of the more important dying drugs of this class, beginning with those which belong to the animal kingdom, and proceeding to the vegetable.

C H A P. VIII.

Of Prussian Blue.

“ Presque tous les arts doivent leur naissance au hazard ;
 “ ils ne font en general, ni le fruit des recherches
 “ ni le resultat des combinaisons ; mais tous ont un
 “ rapport plus ou moins marqué avec la Chymie ;
 “ et elle peut en éclairer les principes, en reformer
 “ les abus, simplifier les moyens & hater leur pro-
 “ gres.”

CHAPTAL, *Elemens de Chymie.*

MANY reasons induce me to consider the tinting matter of Prussian blue as an *animal adjective colour**, which becomes blue when united to iron and to some other metallic bases ; but is at the same time capable of producing other very different colours, when combined with certain other metallic oxides or bases.

The first discovery of Prussian blue, or prussiate of iron, as related by Stahl, was

* I know that some vegetable, and perhaps some fossil matters, possess a power of producing blue precipitates with iron ; but however these may resemble in appearance the Prussian blue, their properties are not identically the same.

like many other interesting discoveries, purely the effect of accident. About the year 1710, *Diesbach*, a chymist at Berlin, wishing to precipitate the colouring matter of cochineal from a solution or decoction, in which it was combined with a portion of green vitriol, or sulphate of iron, borrowed for that purpose from his neighbour Dippel, an alkali, upon and from which the latter had several times distilled an animal oil, and which had thereby become impregnated with the animal colouring part of Prussian blue: consequently this alkali, when mixed with the decoction of cochineal, or rather with the iron contained therein, immediately and most unexpectedly produced a very beautiful blue colour. The experiment being repeated, and always with the same effect, *Diesbach* availed himself of the discovery; and this new colour was made known and sold under the name of Prussian blue. The means of producing it were however kept secret until the year 1724, when Dr. Woodward published an account of the process in the Philosophical Transactions. The cheapest way of preparing this animal blue is, by burning dried blood, horns, hooves, hides, tendons, and other animal substances, so as to reduce them to coal; which is afterwards to be calcined with three times its weight of pot-ash in an iron vessel. After about twelve hours of calcination, the mixture generally appears like a soft paste, and then it is to be thrown into tubs nearly filled with water, and being there dissolved, the solution is filtered, and mixed with another, composed of three parts of alum, and one of cop-

peras, in a sufficient quantity of water. By this mixture, the animal colouring matter becomes united to the oxide of iron, and subsides with it to the bottom of the liquor of a blue colour; and this is to be separated by the filter.

The oxide of iron, as Mr. Berthollet observes, may combine in different proportions with the colouring part of Prussian blue. Where it is in excess, the compound will be yellow; but when the oxide is in a smaller proportion, the colour will be blue. All acids, and particularly the muriatic, are capable of dissolving the excess of iron, so as to bring the compound to the proper state and appearance of Prussian blue. But farther than this, acids have no power of decomposing or dissolving any part of it. The animal colouring part of Prussian blue (separated from the oxyd of iron), is called the Prussian acid, though I think improperly, because there is apparently no more reason for calling it an acid, than there would be in giving that name to the colouring particles of cochineal, and most other dying drugs. It is indeed commonly united to a portion of phosphoric acid, not because this last is a necessary constituent part of it, but because it naturally exists in the different animal substances, from which the Prussian colour is obtained. Scheele has described a process for obtaining the Prussian acid, which I beg leave hereafter to call the Prussian Colouring Matter, in its purest state; and in this state, though capable of recomposing Prussian blue, with the oxide of iron, it contains

contains no phosphoric acid, and therefore this acid cannot be a necessary component part of the Prussian colouring matter.

Prussian blue, though not soluble by acids, dissolves readily both by pot-ash and soda in their caustic, and also their mild states; and the solution is then colourless, or at most only of a very pale straw colour. This solution, when made with pot-ash, is denominated prussiate of pot-ash, and when with mineral alkali, prussiate of soda. It contains a portion of iron in a state of solution, and therefore the blue colour may be restored by any of the acids, in some degree at least.

Ammoniac or volatile alkali, digested in a moderate degree of heat upon the Prussian blue, dissolves and unites with the colouring matter, forming with it a prussiate of ammoniac.

Lime-water also, moderately warm, dissolves the Prussian colouring matter, (as M. Fourcroy first observed,) and holds it in solution without the oxide of iron. This solution, or prussiate of lime, is of a pale yellow colour.

I have stated these facts respecting the Prussian blue, because they are particularly connected with its use in dying. Those who wish for farther information respecting it, may refer to an interesting "Memoire" on this subject, by Mr. Berthollet, of which an extract is contained in the first volume of the Annales de Chymie. He concludes, that the Prussian colouring matter consists of azote, hydrogene, and carbone, combined

combined in certain proportions, not yet accurately ascertained; and that animal substances assist in forming it, by supplying a portion of azote which they contain.

The uncommon beauty and lustre of the Prussian blue, have occasioned many endeavours to apply and fix it equally and permanently as a dye. The late Mr. Macquer proposed two methods of doing this, but neither proved successful. In the first he soaked the stuffs in a solution of alum and copperas, and then in a diluted prussiate of pot-ash (Prussian blue dissolved by pot-ash); and lastly, in water a little soured by sulphuric acid, in order to dissolve and remove any superfluous oxide of iron. By doing this repeatedly, he produced a very beautiful blue colour, but it took unequally, and the texture of the silken and woollen stuffs was rendered very harsh.

In Mr. Macquer's second process the stuffs to be dyed were boiled in a solution of alum and tartar, and afterwards in water containing Prussian blue, which had been finely powdered. In this, however, the colouring particles were only suspended, without being dissolved, and therefore, though they were applied to the fibres of the stuffs, it was without any chymical union, and so sparingly as only to produce very faint shades of colour.

The Abbé Menon recommended a different process for dyeing linens and cottons with the Prussian blue. They were first dyed black in the usual way, with a ferruginous basis; and then

then soaked a few minutes in a diluted solution of Prussian blue, made by pot-ash; after which they were boiled in water with alum, and took thereby a deep blue. In this case the Prussian colouring matter seemed to exert a strong attraction upon the oxyd of iron contained in the black dye, and thereby to decompose and separate the vegetable colouring matter (of galls, &c.) and in its stead to combine with the ferruginous basis. Mr. Berthollet, however, observes, that this effect does not take place unless the Prussian blue has been dissolved with an excess of pot-ash, and I am persuaded it is chiefly owing to the boiling with alum which discharges the colouring matter of the galls, &c. leaving only that of the Prussian blue united to the ferruginous basis.

Some years since M. Roland de la Platriere published among the "Arts et Metiers" of the Royal Academy of Sciences at Paris, an account of another method practised at Rouen for dying with the Prussian blue, in many respects similar to Mr. Macquer's second process, but with this difference, that the Prussian blue in fine powder was suspended, not dissolved, by a diluted muriatic acid, instead of pure water; a change which seems to have been attended with some advantage, though it was with difficulty, and not without many precautions and tedious operations, that an equal colour of sufficient body could be obtained; and then, though highly beautiful, it was not in a state of chymical combination with the fibres of the cotton velvets, for which it was principally used, and therefore was liable to be easily abraded by wearing

wearing and friction, especially in those places where it had been folded. Air, however, did not weaken the colour in any degree, nor was it injured by acids.

A little time before this, M. le Pileur d'Apligny announced to the world that he had discovered the means of dying a blue, as far exceeding all other blues in beauty and lustre, as the cochineal scarlet exceeds the common reds. He, however, kept his process secret, until the offer of a premium induced him to make it public. He began it by impregnating the stuffs to be dyed with an iron basis, which he prepared by deflagrating equal parts of old iron and saltpetre in a crucible, afterwards washing the residuum and dissolving it in vinegar and bran-water. This being sufficiently diluted, was applied as a mordant in the usual ways to the stuffs, which were afterwards well rinsed, and dyed in a preparation of Prussian blue, made by dissolving two pounds thereof (in the moist state in which it is first precipitated) by half a pound of pot-ash, in boiling water, and afterwards adding three ounces of common oil of vitriol, or an equivalent portion of nitric acid, so as to neutralize the alkali, without precipitating the colour. A sufficient quantity of this put into a dying vessel, with hot water, and the stuffs, previously impregnated with the iron mordant, being dyed therein, they became at first green, and afterwards of a beautiful blue colour; which was, however, still liable to take unequally, and therefore M. d'Apligny's process, as far as I can learn, has never been carried into any considerable use.

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In the thirteenth Volume of the "Annales de Chymie," (for April last,) Mr. Berthollet gives an account of certain ideas which had occurred to him respecting the defects of all the means used for dying with Prussian blue, and of some experiments made at his desire by Mr. Vidmer, of the celebrated calico-printing establishment at Jouy, for correcting these defects. It was found by these experiments, that pieces of cotton, impregnated with the acetite of alumine or iron liquor, notwithstanding all possible endeavours to apply it equally, took up the colour of Prussian blue (first dissolved by pot-ash, and then mixed with either sulphuric or muriatic acid) so very unequally, as to leave no hope of success in this way. Mr. Berthollet accounts for this inequality of colour, by supposing that one part of iron is sufficient for six of the Prussian colour; and that therefore the slightest difference in the distribution of the particles of that metal in the mordant, becomes very sensible when the Prussian colouring matter is afterwards superadded thereto.

Mr. Vidmer was particularly struck with the greens which were produced with the Prussian blue, upon patterns previously dyed olive in the usual way by the iron liquor and weld, which greens greatly surpassed in beauty all those given by any other means.

Mr. Berthollet, by experiments which were afterwards made separately from Mr. Vidmer, discovered that the solution of Prussian blue by lime water (prussiate of lime) succeeded as well

well as that by pot-ash, and that it required less care respecting the proportions: but he thinks the alkaline solution will have the advantage of being afforded cheaper, because when animal matters have been calcined with pot-ash, nothing more will be necessary than to saturate the excess of alkali, by adding to it a little Prussian blue.

Mr. Berthollet's method was to dilute the prussiate of lime with three or four times as much water, or to dilute with a large quantity of water, a small one of the prussiate of pot-ash, and then to mix with it a little sulphuric acid, and keeping the liquor at a heat of between twenty and thirty degrees of Reaumur's thermometer, to immerse the cotton, linen, or silk therein, (having first soaked it in warm water,) and turn it over a winch, &c. as usual, in order that the colour might be equally applied. The dye was found to take sufficiently in a few minutes, and then the stuffs were taken out and washed in cold water. He found the sulphuric acid preferable to the muriatic.

Cotton and silk previously dyed gray or brown, with galls or other nigrescent vegetable colouring matters, applied to a ferruginous basis, acquired by the process just mentioned a blue colour, proportioned to the depth of the former brown or gray; and those which had been previously dyed olive, by the application of weld, or other adjective vegetable yellows, took also a beautiful green, proportionate to such olive colour. He says nothing of the effects

fects of this method of dying on wool, having made scarce any trials therewith.

Cotton and silk dyed black by the ordinary means, were found, by superadding a blue in Mr. Berthollet's method, to become more perfectly black, as well where the original colour had faded, as where it had been but imperfectly produced at first. He cautions against using too much acid, as well as against making the dying liquor too hot, and keeping the stuffs too long therein, especially the silk, which would thereby lose some of its lustre and softness.

One great defect, however, attending this method of dying, especially upon cotton, is, that the stuffs, to which the Prussian blue has been applied, will not bear washing, because, though the colour resists air extremely well, the alkali contained in soap readily dissolves and separates the Prussian colouring matter. As a remedy for this defect, Mr. Berthollet recommends washing the cottons, dyed by his process, with bran and water, instead of soap, which, he says, will likewise have the advantage of preserving the other colours of printed cottons; or rather of not injuring them, as washing with soap generally does in some degree. Among the effects mentioned by Mr. Berthollet, that which I thought the most surprising was, the change of what he (improperly) calls an *olive* colour, produced by weld and iron liquor, to a very beautiful green, by the application of Prussian blue in the way before described. The *green* in this instance could not be produced without a mixture of *yellow* with the blue; and weld, the only colouring

colouring substance from which it could in this case be obtained, never would afford any such colour without the aluminous or some other basis very different from iron. I determined therefore, as soon as possible, to ascertain the truth respecting this point; and for this purpose I took a large piece of cotton, which had been printed in parallel longitudinal stripes, first with a mixture of iron liquor and galls, next with iron liquor only; then with a mixture of iron liquor and the aluminous mordant (acetite of alumine); and lastly with the aluminous mordant only; then followed a white stripe to which nothing had been applied, and these were repeated so as to cover the piece. This I dyed in the usual way with a decoction of Quercitron bark, and thereby the first stripe became black, the second of a dark drab colour, the third of an olive, and the fourth yellow. I then took a solution of pot-ash, fully saturated with the Prussian colouring matter, and poured some of it into a large vessel nearly filled with moderately warm water, to which I added a large proportion of oil of vitriol (sulphuric acid): this, from its weight, sunk to the bottom. I took care, however, by stirring, to mix it thoroughly with the liquor; which became uniformly blue, and had a sour taste. I then tore off a strip of the dyed cotton of the whole breadth of the piece, and immersed it for a single minute only in the liquor; when, on taking it out, I found that every particle of the colouring matter of the galls and Quercitron bark had been discharged, and replaced by the Prussian colouring matter upon the stripes where an iron basis had been at first applied, nearly according to the quantum of that basis.

basis. The first stripe, therefore, instead of being black, was of a very full, deep, strong blue colour; the second was sufficiently full, though very sensibly weaker; and the third was still weaker; the fourth, to which the aluminous basis only had been applied, was of a very pale bluish colour, almost as slight as the fifth, which had not been impregnated with any basis or mordant. To diminish the excess of sulphuric acid in the liquor, as well as to replenish it with colouring matter, I added thereto a farther portion of prussiate of pot-ash, which being properly mixed, I immersed another strip torn from the same piece of cotton, and taking it out also, after a single minute, I found that in this instance the excess of sulphuric acid had not been great enough to discharge the colouring matter of the galls, though it had totally discharged that of the Quercitron bark. I had, therefore, instead of a very dark blue on the first stripe, a very full black, greatly superior to what it had been originally, the black from galls and iron having become much more intense by an additional body of blue colour. All the other stripes were very similar to those of the preceding trial. I then perfectly neutralized the excess of acid in the dying liquor, by adding to it a sufficient quantity of prussiate of pot-ash; and a third strip of the same cotton being put into it for the same space of time, I found that none of the colouring matter of the Quercitron bark was discharged in those parts where it had been united to the aluminous basis, though it appeared to have been decomposed and separated from the ferruginous, and its place supplied by the colouring matter of the Prussian blue. I

had therefore on the second stripe a blue colour, instead of the drab which the Quercitron bark had produced with the iron liquor; and on the third stripe, instead of an olive, I had a very beautiful green, composed partly of the yellow from the Quercitron bark and the aluminous basis, and partly of the blue which the Prussian colouring matter had produced on the same stripe, by uniting with the ferruginous particles of the iron liquor, originally mixed with the acetite of alumine, and applied as a mordant upon that stripe. The yellow upon the fourth stripe remained in full perfection; and the fifth stripe was perfectly white, having been quite freed from a slight discolouration which the Quercitron bark had produced on it in the dying vessel. By this, and many similar experiments, made some of them with weld instead of Quercitron bark, I clearly perceived that Mr. Berthollet must have been mistaken, when he supposed that the olives which were changed into beautiful greens in the manner before mentioned, had been given by the weld and iron liquor *only*, because no such effect can be produced either from that or any other adjective vegetable colouring matter, without the aid of alumine, or of oxide of tin, to produce a yellow, whilst the ferruginous basis, by attracting the Prussian colour, produces a blue, the other component part of the green. I ascertained this fact more completely by extending my experiments to woollen cloth, of which Mr. Berthollet says nothing in this respect. I began by dying pieces of white broad cloth, some with weld and copperas, others with Quercitron bark and copperas, which in both cases produced nearly the same

same drab colours; and the pieces being so dyed, I immersed them in different portions of diluted prussiate of pot-ash neutralized, with sulphuric acid, a little more than blood-warm, in which they all, after ten or fifteen minutes, became blue, the Prussian colouring matter having decomposed and separated that of the weld and Quercitron bark, which by suitable experiments I afterwards found to be contained in the several liquors where the Prussian colouring matter had before been suspended. If instead of dying the cloth with weld or Quercitron bark and copperas only, I used alum along with copperas, an olive was produced; and this being soaked as before mentioned in warm diluted prussiate of pot-ash, neutralized with sulphuric acid, produced a green; the alum and Quercitron bark or weld furnishing a sufficient quantity of yellow for that purpose. In all these and many other experiments I found, that though the Prussian colour in this way readily decomposed and separated most of the adjective colours united to a ferruginous basis, for which it has a strong attraction, it had not any sufficiently strong for the aluminous basis to separate the colouring matters combined therewith: and hence in all cases where a portion of alumine had been united with iron, to form the basis or mordant, and an olive colour had been thus produced by weld or Quercitron bark either upon cottons, silk, or wool, a green invariably resulted, from an application of the Prussian alkali with sulphuric acid, unless where this acid was made to predominate so greatly as to decompose, even that part of the vegetable colouring matter which adhered to the aluminous

part of the basis. By reflecting upon these facts, I was led to a method of applying the Prussian blue for dying upon woollen, silk, and cotton, which seems to me capable of obviating every difficulty hitherto attending its use for these purposes. I have already mentioned Mr. Berthollet's opinion, that the inequality of colour to which the dying with Prussian blue is liable, arises from the difficulty of applying the ferruginous particles alone equally to all the fibres of the cloth; though this may be easily done, when the particles of the iron are combined with those of different adjective vegetable colours; I therefore boiled up what I conceived to be suitable proportions of copperas, with Quercitron bark, fustic, and logwood separately, and then dyed a piece of woollen cloth in each of these mixtures, by boiling it therein for ten or fifteen minutes; I chose these vegetable dying drugs, without any regard to their particular colours, only because they were cheaper than any others, regard being had to their proportions of colouring matter, and because they do not contain any mixture of that particular substantive colouring matter found in galls, sumach, &c. which the Prussian colour would be less capable of decomposing and discharging. The pieces so dyed being afterwards separately immersed in warm diluted prussiate of pot-ash, neutralized by sulphuric acid, became all equally and beautifully blue. It must, however, be observed, that this does not always happen, because when too much copperas is employed in the dying with Quercitron bark, &c. there will be an excess of calx of iron applied to the fibres of the wool, which, from its rusty yellow colour,

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will give the Prussian blue a greenish tinge. This, however, may be readily discharged, by passing the cloth through warm water, slightly soured by muriatic acid; though a few experiments would be sufficient to ascertain exactly the quantity of copperas necessary for producing any particular shade of blue in this way upon any given quantity of cloth, and thereby obviate all difficulty on this point. It is necessary always to apply the Prussian colouring matter in a moderate heat, otherwise it will be precipitated by the sulphuric acid, and rendered unfit for this purpose, unless dissolved again by pot-ash, lime, &c.

I shall offer something more respecting the use of Prussian blue for dying *green* upon woollens, when I come to treat of the properties of Quercitron bark.

To ascertain whether any affinity existed between the aluminous basis and the colouring matter of Prussian blue, I took a piece of cotton which had been printed with the aluminous mordant, and cleansed as usual for topical dying, and immersed it in warm diluted prussiate of pot-ash; seeing, however, at the end of fifteen minutes that it had acquired no colour, I put into the liquor a small proportion of a solution of iron by muriatic acid, which rendered it blue, and the cotton soon became of that colour pretty equally, without any manifest difference of colour in the places to which the aluminous mordant had been previously applied. Taking the cotton out of this dying liquor, I tore off a bit of it, and washed it with soap,

P 3

which

which soon discharged all the colour, excepting where the cotton had been impregnated with alumine, and there it was considerably weakened, though enough remained to show that it was attracted and rendered more fixed by the aluminous basis. Another bit of the same cotton was immersed in a solution of ammoniac, (vol-alkali,) which having a power of decomposing the Prussian blue, I supposed it would weaken, if not wholly discharge the colour. To my surprize, however, I found it greatly augment the blue, which before had been rather pale, and give it almost the appearance of what is called garter blue; an effect which will perhaps be the less surprizing, if we consider that volatile alkali, like the Prussian colouring matter, is an animal production, and composed of the same principles, excepting only the carbone, which it wants, and which exists in the latter.

Another bit of the same cotton being put into water, very slightly tintured with a solution of copper by volatile alkali, the blue colour in a very sudden and surprizing degree augmented to an intensely deep garter blue or violet, much exceeding that produced by the ammoniac alone; and this being afterwards washed with soap, the colour of those parts where the aluminous mordant had been at first applied, was still better fixed than it had been on the like parts by the volatile alkali alone in the preceding trial.

Another piece of the same cotton being immersed in water, with which a very little muriate of copper had been previously mixed, soon became

became of a deeper blue, but without any of the purple or violet hue which had been produced in the two preceding instances.

This piece being afterwards washed with soap, I perceived that the colour where the aluminous mordant had been applied was still much more firmly fixed than it had been by any other means. Indeed after a severe washing, which completely discharged the colour every where else, the spots or parts impregnated with alumine retained a full strong blue, which the soap had indeed turned a little towards a violet colour; but after being well rinsed in clean water, it returned again to its proper complexion, and stood a long exposure to weather unaltered, and afterwards two or three severe washings with soap, without much diminution of colour*. It must, however, be remembered, that if copper thus manifestly fixed the Prussian blue, it was only in those parts where the aluminous mordant had been at first applied; since the other parts of the cotton were washed white as soon as they were on the bit, to which nothing had been applied after it became blue; so that there can be no doubt but what both alumine and copper together greatly contribute to fix the colouring matter of Prussian blue. The copper indeed, as we shall presently see, possesses a power of uniting therewith, and producing one of the

* In this and the other pieces the blue upon the spots impregnated with alumine, after it had been weakened by washing, was rendered nearly as strong as ever, by dipping them into water slightly soured with sulphuric acid, so as to decompose and neutralize the alkali which had been imbibed from the soap in washing.

most permanent of colours even upon linen and cotton; a fact which I believe never was imagined by any one, until it very lately fell under my observation. From these proofs of the utility of an aluminous basis in fixing the Prussian blue, it probably would prove advantageous to prepare woollens by the usual boiling with alum, or alum and tartar, before they are dyed with copperas and Quercitron bark, fustic, or logwood, for a Prussian blue. But in this case it will be necessary to mix a greater proportion of oil of vitriol in the prussiate of pot-ash, or of lime, in order that there may be an excess of acid to assist in discharging these vegetable colouring matters, otherwise instead of a blue they would produce a green, or a black, where logwood had been employed with the copperas.

Having soaked pieces of silk and of cotton in the diluted prussiates of pot-ash, soda, lime, and ammoniac, or volatile alkali, separately, and afterwards dried them, I applied to each, by the pencil, a little of the solutions of all the metals and semi-metals in most of the different acids and alkalies, where they were soluble in the latter, in order to see the effects of all these several bases upon the Prussian colouring matter. I should tire the patience of my readers, were I particularly to describe the results of these different combinations, especially as no words can convey adequate ideas of the great variety of shades and degrees of colour, and particularly of the blue produced by them, and which varied prodigiously in its degrees of fullness and brightness, as well as in its inclination towards the purple and violet on one hand, and green on the other;

other; and indeed the diversities of blue only, (which was the colour produced by much the greatest number of metallic solutions,) would alone constitute a very pleasing variety of colour in the way of printing upon silk or cotton. There were, however, several other colours produced at the same time; *e. g.* The nitro-muriate of gold produced very beautiful green, inclining a little to the yellow, which, by washing, changed somewhat to the olive, whilst the nitro-muriate of platina produced a green inclining to the blue. The muriate of tin, and the nitrate of mercury, produced greenish yellows, and the nitrate of nickle an olive brown. But the most remarkable, and probably the most useful effect of these applications, was, a very full, striking, lively colour, of which I cannot by words give my readers a perfect idea, because I do not remember to have ever before seen any colour exactly like it, and there is I believe no name in any language suited to it. It approaches nearest, however, to the highest and brightest colour of new copper, but inclines more to the red, and is accompanied with a kind of metallic shining lustre, which in my eyes appeared very agreeable. This colour (which I shall call the red copper colour, until a better name be given it) was produced by the different solutions of copper in the sulphuric, the nitric, the muriatic, and the acetous acids separately; and particularly well by that in volatile alkali. Copper, however, was not the only metallic basis which produced this colour, though it was the cheapest, and therefore the most suitable for this purpose. The nitrates of silver and of cobalt produced exactly the same colour

colour as the solutions of copper, and they all equally possessed the singular property of fixing the Prussian colouring matter so firmly to this red coppery hue, that, besides resisting acids, no number of washings with soap, nor exposure to weather for the longest space of time, seem capable in the least degree of diminishing either its body or its lustre, and therefore I cannot help thinking that it may prove highly useful, and more especially for calico-printing, by way of *topical* application upon cottons, and perhaps in dyeing cotton-yarn for stripes of muslins, borders of handkerchiefs, &c. I have not experienced the same effect from a *direct* mixture of the Prussian colouring matter with a solution of copper, not even when I put the prussiate of ammoniac into a solution of copper by ammoniac (which I thought most likely to answer); but have always found it necessary either to apply the Prussian colouring matter (dissolved by pot-ash, soda, ammoniac, or lime) first to the linen, cotton, or silk, and after suffering it to dry, to apply some one of the before mentioned solutions of copper, silver, or cobalt; or else to apply the metallic solution first, and then the Prussian; but in this last method, I have not found any solution of copper answer so well, excepting that by the ammoniac, or volatile alkali.

Many of the other colours (besides the coppery red last mentioned) which were produced on silk and cotton from the Prussian colour, and the different metallic solutions, stood several washings with soap, and particularly the blues, of different shades and complexions. They all perfectly

perfectly resisted the impressions of air; and it seems to me that they are capable of very useful applications in this way, and particularly suited for a kind of printing or painting upon silk, which for this purpose might be impregnated with a diluted colourless prussiate of pot-ash, soda, or ammoniac, or with a prussiate of lime, and made to receive a pleasing variety of colours from the different metallic solutions, applied either by the pencil or the block; and after drying, a farther addition of colours might be made, by rinsing the silk in clean water, to carry off the Prussian colour from the parts where it was not wanted, and make room for the application of many different substantive colours, which either have been or will be mentioned in the course of this work.

Similar applications might also be made to muslins; but in that case, as some of the Prussian colours would be liable to injury from soap, it would be proper to wash them with bran or oatmeal in water. I ought farther to mention, that in some instances the same metal dissolved by different acids does not produce the same colour with the Prussiate of pot-ash, &c. Thus, *e. g.* though the nitrates of silver and cobalt produce the red copper colour before described, the muriates of these metals produce a blue, and though the nitrate of lead produces a strong lively blue, the muriate of that metal produces no colour with the prussiates of lime, ammoniac, &c. To conclude this subject, I shall only add, that when I first observed the red copper colour produced as before mentioned, and experienced its fixed unalterable nature, I strongly suspected that the
oxyd

oxyd of iron made a part of it, more especially as it had first occurred to me, when applying the ammoniate of copper to the prussiate of pot-ash; but I always found the same effect from the prussiates of ammoniac and lime, in which, by suitable means, I satisfied myself that no iron was held in solution; and I moreover found, that no solution of iron would produce any such effect with any of the solutions of copper.

CHAP. IX.

Of Adjective Colours from European and Asiatic Insects.

“ La laine & la soie qui montreroient plutot dans leur
 “ couleur naturelle la rusticité de l'age que l'esprit
 “ de l'homme & la politesse du siecle, n'auroient
 “ qu'un mediocre commerce si la teinture ne leur
 “ donnoit des agréments qui les font rechercher &
 “ desirer meme par les nations les plus barbares.”

COLBERT, *Instruction generale*
pour la Teinture, &c. 1672.

ART. I.

THE kermes (*Coccus Illicis*, Lin.) is an insect which the Greeks and Romans distinguished by the names of *Coccus Baficus*, *Coccus Infectorius*, *Coccum Squarlatinum*, *Gratum Tinctorium*, &c. and which is found on a small species of oak (the *Quercus Coccifera* of Lin.) growing in most of the southern parts of Europe, as well as in many parts of Asia. According to Father Plumier, the Arabian name of this insect *kermen*, or *kermes*, signifies a little

a little worm ; and Pliny, though he considered it as the excrescence of a tree, mentions it as speedily becoming a worm : " *Coccum Illicis* " *celerime in vermiculum se mutans* *."

This insect appears to have been one of the most ancient of all dying drugs, and that which produced the colour originally known by the name of scarlet in England, as it had been by that of coccus among the Romans. Pliny indeed inaccurately describes it as a kind of rose colour, (*coccus, qui in rosis micat*,) whereas it is in fact a red, approaching nearly to that of florid arterial blood. Ctesias and Ælian also mention a crimson colour produced from insects, which probably were either the kermes or lacca insects. Sir John Chardin, in an account of Persia, (published in Harris's Voyages,) remarks, that in certain parts of Media " they " gather *cochineal*, though in no great quantity, nor for any longer time than eight days " in summer, when the sun is in Leo ; for before that time the people (continues he) say " it doth not come to maturity ; and after it, " the worm from which they draw the cochineal " makes a hole in the leaf in which it grows, " and is lost. The Persians call cochineal " kermes, from kerm, which signifies a worm, " because it is extracted out of worms." But in this instance the term cochineal, which belongs peculiarly to an American insect, is very improperly applied to the kermes.

The first volume of the Philosophical Transactions contains a paper, written by M. Verney,

* Lib. xxiv. sect. 4. fol. 327.

then

then of Montpellier, respecting the Natural History of the Kermes; and M. Reaumur afterwards described them very minutely in the fourth volume of his "*Memoires pour servir a l'Histoire des Insectes.*" But the most useful information on this subject seems to be that which M. Chaptal lately gave to M. Berthollet, and which he has published in the second Volume of his *Elemens de l'Art de la Teinture*. The male insect passes from its vermicular state through the usual forms into that of a fly with four wings; though the female never acquires any wings, but fixes herself on a leaf of the oak, where, being impregnated by the male, her size gradually increases (as the eggs enlarge) to that of a juniper-berry, and she at the same time becomes of a reddish brown colour. When the eggs are on the point of hatching, the females should be collected and exposed to the steam of vinegar, to kill them and prevent their young from being brought forth; and afterwards they should be dried by being spread out on cloths, by which treatment they acquire the colour of red wine. M. Chaptal says, that a single person may collect from one to two pounds of kermes in a day. Formerly very great quantities of these insects were gathered, particularly in the southern parts of France and Spain, for dying; but their use in this way has been almost wholly superseded, at least in Europe, by that of the cochineal, which affords a more beautiful, and even a cheaper colour, since one pound of the latter will dye as much as twelve pounds of kermes, which probably could not be now had in any quantity for less than half a crown the pound. But the kermes red or scarlet, though
less

less vivid, is more durable than that of cochineal, and much less liable to be changed by soap, acid, mud, &c. The fine blood reds seen at this time on old tapestries in different parts of Europe, unfaded, though many of them are two or three hundred years old, were all dyed from kermes, with the aluminous basis, on woollen yarn.

To prepare wool for the kermes dye, it is to be boiled in water, with about one-fifth of its weight of alum, and half as much of tartar, for the space of two hours, and afterwards left in the same liquor four or five days, when being rinsed, it is to be dyed in the usual way, with about twelve ounces of cochineal, for every pound of wool. Scarlets, &c. given from kermes, were called *grain colours*, because that insect was mistaken for a grain; and afterwards the same appellation was for the same reason given to cochineal colours.

Wool prepared with a nitro-muriatic solution of tin, (as is now practised for the cochineal scarlet,) and dyed with kermes, takes a kind of aurora, or reddish orange colour. Cotton prepared with the printer's aluminous mordant, and dyed with kermes, exhibits a fine red, inclining to the crimson shade; but this will gradually, though slowly discharge, and the colour be weakened in washing.

I had formerly made some experiments which seemed to promise success in fixing the colour of kermes more permanently on cotton; and wishing to repeat and extend them, I endeavoured

to procure kermes sufficient for this purpose; but finding none in Great Britain, I have taken steps to secure a supply from the south of France, which however not being yet come to hand, I shall defer what I may have farther to communicate on this subject, until the publication of my next volume.

ART. II. Lacca, or gum lac, is brought from different parts of the East-Indies, and in different forms. In its natural state it adheres externally to the small branches of certain shrubs, and is then called stick lac. When separated from the sticks, and garbled, it is denominated *seed lac*; and this liquefied by heat, and formed into cakes, is called *lump lac*. Seed lac, deprived of its colouring matter, by being boiled in hot water, then liquefied by heat, strained, and formed into thin transparent plates, becomes *shell lac**. Gum lac is the production of certain little insects of the coccus genus, of which the first account deserving our notice seems to have been that communicated by Mr. James Kerr of Patna, (through Sir Joseph Banks,) to the Royal Society, and published in the Philosophical Transactions for 1781. According to Mr. Kerr's description of the coccus lacca, when first brought forth in November and December, "the head and trunk form one uniform oval
" compressed *red* body, of the shape and mag-

* Sir William Jones says, "the Hindus have six names
" for Lac; but they generally call it Lâchâ, from the
" multitude of small insects, who, as they believe, discharge
" it from their stomachs, and at length destroy the tree on
" which they form their colonies." Dissertations, &c.
relating to the History and Antiquities, &c. of Asia, vol. ii.

" nitude of a very small louse, consisting of
 " twelve transverse rings; the back is carinate,
 " the belly flat, the antennæ half the length of
 " the body, fili-form, truncated and diverging,
 " sending off two, sometimes three delicate di-
 " verging hairs longer than the antennæ."
 The tail is " a little white point, sending off
 " two horizontal hairs, as long as the body."
 The insect had three pair of limbs half of its
 own length, but no wings were seen by Mr.
 Kerr. As soon as they are brought forth, the
 insects begin to " traverse the branches of the
 " trees upon which they were produced for
 " some time, and then fix themselves upon the
 " succulent extremities of the young branches.
 " By the middle of January they are all fixed
 " in their proper situations, and appear as plump
 " as before, but shew no other marks of life.
 " The limbs, antennæ, and setæ of the tail, are
 " no longer to be seen. Around their edges
 " they are environed with a spissed subpellucid
 " liquid, which seems to glue them to the
 " branch. It is the gradual accumulation of
 " this liquid which forms a complete cell for
 " each insect, and is what is called gum lacca.
 " About the middle of March the cells are
 " completely formed, and the insect is in ap-
 " pearance an oval smooth red bag, without
 " life, about the size of a small cucanical in-
 " sect, emarginated at the obtuse end, full of a
 " beautiful *red liquid*. In October and No-
 " vember we find about twenty or thirty oval
 " eggs, or rather young grubs, within the red
 " fluid of the mother. When this fluid is all
 " expended, the young insects pierce a hole
 Q " through

“ through the back of their mother, and walk
 “ off one by one, leaving their exuviae be-
 “ hind.”

According to Mr. Kerr, the lacca insects in the country where he wrote were found on four species of shrubs: 1st, *Ficus Religiosa*, Lin. 2d, *Ficus Indica*, Lin. 3d, *Plaso Hortus Malabaraci*; and, 4th, *Rhamnus Jujuba*, Lin.— They fix themselves in such multitudes on the branches of these trees, and more especially of the three first, that “ the extreme branches appear as if they were covered by a red dust; “ and their sap is so much exhausted, that they “ wither and produce no fruit.” Birds perching on these branches carry off great numbers of the lacca insects, adhering to their feet, and transplant, by depositing them on other trees where they rest.

“ The gum lacca of this country (says Mr. “ Kerr) is principally found upon the uncultivated mountains on both sides of the Ganges, “ where bountiful nature has produced it in “ such abundance, that were the consumption “ ten times greater than it is, the markets “ might be supplied by this minute insect. “ The only trouble in procuring the lac is in “ breaking down the branches, and carrying “ them to market. The present price in Dacca “ is about 12s. the 100lb. weight, although it “ is brought from the distant country of Assam. “ The best lac is of a *deep red* colour. If it be “ pale, and pierced at the top, the value diminishes, because the insects have left their “ cells,

“ cells, and consequently they can be of no use
“ as a dye or colour:” though the lac itself may
be better for varnishes.

The lacca is capable of being applied to several uses. That of dying, however, is alone the object of our present inquiry; and for this it appears to have been known and employed by the ancients. (See Salmas. Exercit. p. 810.)

By Mr. Kerr's account, the native Indian inhabitants, after extracting the colouring matter of the lac by hot water, mix alum and tamarind water with the decoction, and dye silk and cotton therein.

Of the four species of shrubs upon which the lacca insects are found in the countries adjacent to Patna, according to Mr. Kerr, there is only one, the *Rhamnus Jujuba*, upon which Dr. James Aderfon found these insects near Madras, though he observed them on several species of *Mimosa*, and on some other trees and shrubs. Dr. Roxburgh, of Samulcotta, seems to think, however, that on the coast of Coromandel they only inhabit shrubs of the *Mimosa* kind, and even but three species of this genus. He says, (see *Philos. Transf.* 1791,) that “ some pieces
“ of fresh looking lac adhering to small branches
“ of the *Mimosa cinerea*, Lin. were brought
“ to him on the 20th of November 1789;” and being carefully kept in wide-mouthed crystal bottles, slightly covered, after fourteen days had elapsed “ thousands of exceeding minute
“ red animals were observed crawling about the
Q 2 “ lac

“ lac and the branches it adhered to, and still
“ more were adhering to the surface of the cells.
“ By the assistance of glassess, small imperforated
“ excrescences were also observed interspersed
“ among the holes; two regularly to each hole,
“ crowned with some very fine white hairs,
“ which being rubbed off, two white spots appeared. The animals, when single, ran
“ about pretty briskly; but in general on opening the cells they were so numerous as to be
“ crowded over one another.

“ The substance of which the cells were formed, cannot be better described, (says Dr. Roxburgh,) with respect to appearance, than by saying, that it is like the transparent amber that beads are made of. The external covering of the cells may be about half a line thick, is remarkably strong, and able to resist injuries; the partitions are much thinner. The cells are in general irregular squares, pentagons and hexagons, about an eighth of an inch in diameter, and a quarter of an inch deep: they have no communication with each other. All those I opened during the time the animals were issuing from them, contained in one side, which occupied half the cell, a small bag filled with a thick red jelly, like liquor, replete with what I take to be the eggs. These bags, or utriculi, adhere to the bottom of the cells, and have each two necks, which pass through perforations in the external coat of the shells, forming the before-mentioned excrescences, ending in some fine hairs.

“ The

“ The other half of the cells has a distinct opening, and contains a white substance, like some filaments of cotton rolled together, and a number of the little red insects themselves, crawling about, ready to make their exit. Their portion of each cell is about one half, and I think must have contained near one hundred of these animals. Other cells less forward, contained in this half, with one opening, a thick, red, dark, blood-coloured liquor, with numbers of exceedingly minute eggs, many times smaller than those found in the small bags which occupied the other half of the cells.”

Dr. Roxburgh describes the circumstances and progress of these insects, and particularly the females, through the larva and pupa onwards, to their perfect states, which last they did not reach until near five months. The male insect in the perfect state was about the size of a very small fly, and exceedingly active; with an obtuse head, black eyes, oval brown trunk, six legs for running and jumping, and four membranaceous incumbent wings, of which the anterior pair was twice as long as the posterior; but he had no tail.

The female insect, in her perfect state, was rather smaller than the male, and of a brighter red colour, though less active. Her head and eyes were very small; trunk red, and almost orbicular; abdomen red, oblong, and composed of twelve annular segments; she had six legs for running and jumping, with only two long transparent incumbent wings, and a tail consisting

sitting of two white hairs as long as her body.

“ The eggs, and dark-coloured glutinous liquor they are found in, (continues Dr. Roxburgh,) communicate to water a most beautiful red colour, *while fresh*. After they have been dried, the colour they give to water is less bright; it would therefore be well worth while for those who are situated near places where the lac is plentiful, to try to extract and preserve the colouring principles by such means as would prevent them from being injured by keeping. I doubt not but in time a method may be discovered to render this colouring matter as valuable as cochineal.

“ Mr. Hellot's process (adds Dr. Roxburgh) for extracting the colouring matter from dry lac, deserves to be tried with the fresh lac, in the month of October or beginning of November, before the insects have acquired life; for I found the deepest and best colour was procured from the eggs while mixed with their nidus. His process is as follows: Let some powdered gum lac be digested two hours in a decoction of comfrey root, by which a fine crimson colour is given to water, and the gum is rendered pale or straw coloured. To this tincture, poured off clear, let a solution of alum be added; and when the colouring matter has subsided, let it be separated from the clear liquor and dried. It will weigh about one-fifth of the quantity of lac employed. This dried secula is to be dissolved or diffused in warm water; and some solution

“ of

“ of tin is to be added to it, by which it ac-
 “ quires a vivid scarlet colour. This liquor is
 “ to be added to a solution of tartar in boiling
 “ water, and thus the dye is prepared.

“ In India (says Dr. Roxburgh) comfrey roots
 “ are not to be had; but any other mucilaginous
 “ root, gum, or bark, would probably answer
 “ equally well. On some parts of the Coroman-
 “ del coast, if not over it all, a decoction of the
 “ seeds of a very common plant, (Cassia Tora
 “ of Linnæus,) which is extremely mucilagi-
 “ nous, is used by the dyers of cotton cloth blue,
 “ to help to prepare the blue vat. It *suspend*
 “ the indigo until a fermentation takes place to
 “ dissolve it, and also helps to bring about that
 “ fermentation earlier than it otherwise would.”

Probably some methods of extracting the colouring matter of fresh lac, similar perhaps in a considerable degree to that proposed by Dr. Roxburgh, have been already attempted in some parts of India. A gentleman, to whom I have already had occasion to allude several times, lately received from Bengal, where he had formerly resided, a parcel of a colouring matter, which had very much the appearance of powdered cochineal, of which he gave me a few ounces, calling it East-Indian Cochineal, with a request that I would try its effects in dying scarlet. I happened then to have by me a piece of cloth which I had previously prepared for receiving a scarlet from cochineal, (upon a new principle to be hereafter explained,) by impregnating it with a muriatic solution of tin, and a certain portion of yellow colour from the Quer-

citron bark; and I resolved to see whether this East-Indian colouring matter would yield a crimson, capable, when fixed as a dye in the cloth so impregnated and made yellow, of producing a scarlet, as the natural crimson of cochineal would do by the same means. But on boiling the cloth in question with this East-Indian colouring matter in water, I found it wholly insoluble by this menstruum. However, upon taking out the cloth, and adding a little pearl-ash, the water immediately assumed a fine crimson colour, the alkali having, as I afterwards discovered, separated the colouring matter from a portion of alumine which had been employed to precipitate it (in India), and to which it was too intimately united to be dissolved by water only. Having thus obtained an alkaline solution of the colouring matter in question, I decanted off the clear crimson liquor, added to it a little muriate of tin, principally to neutralize the alkali, and precipitate any alumine which might have been dissolved by it, and then dyed the piece of cloth before mentioned, which took a very good scarlet, much better indeed than I have ever been able to give from the lac brought to this country in its natural form; though from many circumstances and subsequent trials, I am fully persuaded that the colouring matter which produced this effect, was in reality nothing but the colouring matter of lac, extracted either when fresh, or by some particular means when dried, and afterwards precipitated either wholly or in part by alum.

A few years since, some persons in this country formed an establishment for extracting the colouring

colouring matter of dried lac; but it probably did not succeed according to their expectations, since it does not I believe now subsist. An extract, answering tolerably well, may be made from this drug, by merely boiling it in water, straining off the coloured liquor, and evaporating it to a solid consistence. The cells which contain the lacca insects, and the matter of which they are composed, as well as the uses to which they are subservient, seem analogous in many respects to the honey-comb, &c. of bees. The fine red-coloured liquor contained in the cells of the lac is also described by some authors as being sweet to the taste, at the same time that it readily mixes with water. Great use is made of it as a dye by the natives of Assam.

The colours dyed by stick lac approach very nearly to those of cochineal. They are indeed not quite so lively and beautiful, but this defect is in some degree compensated by their being more durable, especially on cottons, where I have employed it with some success topically, with different bases. It has been sometimes a practice to employ a mixture of the colouring matter of lac, with that of cochineal, in producing scarlets, &c. Both require the same basis, and nearly the same treatment, which will be fully described in the chapter respecting the uses of cochineal. At present, however, almost all the lacca brought to Europe is afterwards sent to Portugal, Barbary, &c. and employed in staining goat skins to produce what is called red Morocco leather.

ART.

ART. III. The *Coccus tinctorius Polonicus* is a small round insect very much resembling the kermes in many respects. It used to be collected, in considerable quantities, in the Ukraine and other provinces of Poland, as well as in the Great Dutchy of Lithuania, from about the roots of the German knot-grass or knawel (*Scleranthus perennis*, Lin.). The male only, by a transformation similar to that of the male kermes, becomes a fly, though with but two wings, which are white, edged with red. The females, being impregnated by the male, enlarge their size, and become ready to bring forth their young soon after the summer solstice, at which time they abound most in a crimson juice, which was formerly very much used by the Turks and Armenians in dying wool, silk, and hair, as well as in staining the nails of women's fingers. But the use of these insects, like that of kermes, has been nearly laid aside every where, since the cheaper and more beautiful colours of cochineal have become generally known. This dye was fixed on wool and silk by the usual mordant or preparation of alum and tartar.

Very similar to the *Coccus Polonicus* is an insect, which in many parts of Europe was formerly taken from the roots of the burnet, (*Poterium Sanguisorba*, Lin.) and which was used in different countries, and particularly by the Moors, for dying wool and silk of a crimson or rose colour. Ray, describing this plant, says, "*Hujus radicis adnascitur quibusdam in locis* "*græcum rubrum*, quo utuntur tinctores ad co-

" lozem

PERMANENT COLOURS, &c. 235

“ *lorem carmesinum, unde sunt qui pro cocco*
“ *habent, & coccum radicem appellant monen-*
“ *tibus lacuna & anguillara.*” Hist. Plant.
401.

The *Coccus Uvæ Ursi* of Lin. is also an insect affording a fine red colour, capable of being employed adjectively in dying. It very much resembles the *Coccus Polonicus*, as well in its properties as in its form, but* with this advantage, that it is nearly twice as large.

M. Olivier, in his “Entomologie,” &c. says, the *meloë proscarabé* might furnish a colour useful to dyers and painters; and that some things of this sort might be obtained from a considerable number of the *coleopteres*.

In the next chapter I shall have occasion to mention another insect lately sent from India, and mistaken there for cochineal, with which I dyed a very durable chocolate colour; and probably there are many others capable of being applied in this way.

C H A P. X.

Of the Natural History of Cochineal.

- " Our vallies yield not, or but sparing yield
 " The dyers' gay materials. Only weld,
 " Or root of madder, here, or purple woad,
 " By which our naked ancestors obscur'd
 " Their hardy limbs, inwrought with mystic forms
 " Like Egypt's obelisks." DYER.

THE Cochineal, or *Coccus Cacti* of Linnæus, is arranged among the "Insecta" of the fifth class of that great naturalist; and in the second order, comprehending the "Hemiptera," (half-winged insects, &c.) The body of the male is slender, of a red colour, covered by two wings, spread horizontally, and crossing each other a little on the back, and enabling him to fly or rather flutter. The head is distinct but small, with two diverging slender antennæ; the abdomen or tail is terminated by two small and very long diverging hairs; he has six feet, with which he sometimes jumps like the lacca insect; and hence Linnæus has applied the term "saltatoria," as one of his distinguishing characters. The male insects are but seldom found among the cochineal sent to Europe. The back of the female is hemispherical, and crossed by numerous wrinkles; she is of a dark reddish brown colour; her mouth is a small tubular projection from the thorax; she is without wings, but has six legs; these, however, only serve her to remove during a short interval imme-

immediately succeeding her birth; after which they become useless, and ceasing to grow from inactivity, remain so small as to be afterwards hardly perceptible, at least without a very minute inspection. This circumstance probably occasioned, and certainly confirmed, the belief which prevailed very generally in Europe, during a considerable number of years, that these insects were vegetable grains or seeds.

The cochineal is nourished, perhaps exclusively, by some of the different species of the *Cactus*, or Indian fig, (called by some the prickly pear,) a genus of plants, of which Linnæus describes twenty-five several species, all originally found in America only; of very different forms, and producing fruits of various colours when ripe, according to the species on which they respectively grow; as white, yellow, red, crimson, purple, violet, green, &c. Among these, the red and crimson coloured fruits more especially contain a mucilaginous juice, which communicates the colour of the fruit in a high degree to the urine of those by whom it is eaten. That species on which the cochineal attains its greatest perfection, is denominated *Cactus Cochenillifer* by Linnæus. But the insects live naturally, in their wild state at least, on some of the other species, particularly the *Cactus tuna*, *Cactus opuntia*, and *Cactus pereskia*; all of which, as well as the *Cactus cochenillifer*, belong to that section of *Cacti* which Linnæus distinguishes as "*opuntia compressa, articulis proliferis*," *i. e.* flattened or compressed with prolific articulations. The *Cactus cochenillifer*, however, which the Mexican Spaniards call *nopal*,

pal, is alone cultivated for the purpose of feeding and breeding these insects.

The Spaniards, on their first arrival in Mexico, saw the cochineal employed, as it appears to have been long before, by the native inhabitants of that country, in colouring some parts of their habitations, ornaments, &c. and in staining their cotton; and being struck with its beautiful colour, they gave some accounts of it to the Spanish ministry, who in the year 1523 (as Herrera informs us) ordered Cortes to take measures for multiplying this valuable commodity; but as the Spaniards then in America were careless of every thing but gold and silver, they left this object to the industry of the natives only; which, however, from the large supplies soon after sent to Europe, appears to have been successfully exerted in this respect.

For a number of years the inhabitants of Europe were generally mistaken respecting the nature and origin of cochineal, supposing it to be grain or seed, as has been already observed. The first opinion to the contrary was, I believe, given by the anonymous author of a paper, in the third volume of the Philosophical Transactions, (printed in the year 1668,) in which he supposes cochineal to be an insect "*engendered*" by the fruit of the prickly pear; and being a believer of equivocal generation, he proposes to employ fermentation as a means of engendering and multiplying these insects more copiously.

In the year 1672, a paper written by Lister was published in the seventh volume of the Philosophical

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Iosophical Transactions, concerning the kermes, in which he "conjectures cochineal may be a "sort of kermes." The seventeenth volume of the Transactions, published in 1691, contains some observations concerning the making of cochineal, according to a relation had from an old Spaniard at Jamaica, who says, "cochineal "is the same which we call lady bird, alias cow "lady, which at first appears like a small blis- "ter or little knob upon the leaves of the "shrub on which they breed, and which after- "wards, by the heat of the sun, becomes a live "insect as above, or a small grub."

Early in 1693, Father Plumier wrote and subscribed a declaration, which he delivered to Pomet, affirming cochineal to be an insect living on the opuntia or Indian fig, and that he had seen it in the island of St. Domingo; and de Laet had some little time before described it as feeding on the tuna. Pomet, however, misled by the prevailing opinion on this subject, as well as by several letters which about that time were sent to him from St. Domingo by F. Rousseau, adopted the fallacious accounts of this letter-writer, (who promised to send over to France some of the very plants whose seeds, as he asserted, afforded the true cochineal,) and described this drug as the seed of a plant two or three feet high, bearing pods of a conical form, in which the cochineal grew naturally. (See Hist^e Gen^e des Drogues, &c.)

But groundless as this account was in reality, it obtained so much credit, that no longer than

four years since, a very eminent dyer of this metropolis seriously told me, that having bought a large parcel of cochineal, he actually found among it one of these conical pods, containing cochineal naturally attached to the inside like seeds.

Lewenhoeck, however, by his glasses plainly saw that the cochineal was an insect with six legs; and in a letter, read at the Royal Society the 21st of March 1704, and published in the xxivth volume of the Transactions, he positively contradicted all those who had represented it as a vegetable grain; and declared that, by dissections, he had invariably found eggs, or animalcula, in the supposed grains, and often to the amount of two hundred in each. He also represents these insects as "not produced from worms," but as "at once bringing forth their like."

About the year 1730, Dr. Rutly, then Secretary of the Royal Society, published a Natural History of Cochineal, (in the xxxvth volume of the Transactions,) from a work on this subject by Melchior de la Ruuscher, who had procured from Antiquera in New Spain, the depositions of eight persons, who had been actually employed for many years in the breeding and management of cochineal, and who swore that they were "small living animals with a beak, eyes, feet," &c. and the originals of these depositions, notarially authenticated, were deposited in the archives of the Royal Society. Not long after this, Reaumur, in his *Hist^e des Insectes*,

Insectes, and Dr. Brown, in his History of Jamaica, described the female cochineal with sufficient accuracy; as did Linnæus some time after, from a living female sent to him by Mr. Rolander from Surinam, in the year 1756; though neither of these naturalists had ever seen the male cochineal.

About the beginning of the year 1757, Mr. John Ellis, F. R. S. hearing that the cochineal insect bred in great abundance on the cactus opuntia in South Carolina and Georgia, wrote to Dr. Alexander Garden of Charlestown, South Carolina, for some of the joints of that plant, with the insects thereon, which were accordingly sent the latter end of that year, and laid before the Royal Society. "These specimens (says Mr. Ellis) were full of the nests of this insect, in which it appeared in its various states, from the most minute, when it walks about, to the state when it becomes fixed and wrapt up in a fine web, which it spins about itself.

"In order to find out the male fly, (continues he,) I examined all the webs in these specimens, besides a large parcel which the doctor had sent me picked off from the plants in Carolina, and at last discovered three or four minute dead flies with white wings. These I moistened in weak spirit of wine, and examining them in the microscope, I discovered their bodies to be of a bright red colour, which convinced me of their being the true male insect. To be confirmed in my
R "opinion,

“ opinion, I immediately communicated my
 “ discovery to Dr. Garden, which I accompa-
 “ nied with an exact microscopical drawing, and
 “ desired he would send me some account of
 “ their œconomy, with some male insects of his
 “ own collecting,” which he did in the spring
 of the year 1762, accompanied with the follow-
 ing observations :

“ In August 1759, (says Dr. Garden,) I
 “ caught a male cochineal fly, and examined
 “ it in your aquatic microscope. It is seldom
 “ a male is met with. I imagine there may be
 “ one hundred and fifty or two hundred females
 “ for one male. The male is a very active
 “ creature, and well made, but slender in com-
 “ parison of the females, who are much larger
 “ and more shapeless, and seemingly lazy, tor-
 “ pid, and inactive. They appear generally so
 “ overgrown, that their eyes and mouth are
 “ quite sunk in their rugæ or wrinkles; nay
 “ their antennæ and legs are almost covered by
 “ them, and are so impeded in their motions
 “ from these swellings about the insertions of
 “ their legs, that they can scarce move them,
 “ much less move themselves.

“ The male's head is very distinct from the
 “ neck: the neck is much smaller than the head,
 “ and much more so than the body. The thorax
 “ is elliptical, and something larger than the
 “ head and neck together, and flattish under-
 “ neath; from the front there arise two anten-
 “ næ, (much longer than those of the females,)
 “ which the insect moves every way very brisk-
 “ ly.

ly. These antennæ are all jointed, and from every joint there come out four short setæ, placed two on each side.

" It has three jointed legs on each side, and moves very briskly and with great speed. From the extremity of the tail there arise two long setæ or hairs four or five times the length of the insect. They diverge as they lengthen, are very slender, and of a pure snow white colour. It has two wings, which take their rise from the back part of their shoulders or thorax, and lie down horizontally, like the wings of the common fly, when the insect is walking. They are oblong, rounded at the extremity, and become suddenly small near the point of insertion. They are much longer than the body, and have two long nerves; one runs from the basis of the wing along the external margin, and arches to meet a slender one that runs along the under and inner edge. They are quite thin, slender, transparent, and of a snowy whiteness. The body of the male is of a lighter red than the body of the female, and not near so large."

To Dr. Garden's description, Mr. Ellis, in an account of the male and female cochineal insects, accompanied with drawings, &c. (in the fifty-second volume of the Philosophical Transactions,) adds, that the female has a remarkable proboscis or awl-shaped papilla, arising in the midst of the breast, which Linnæus calls the rostrum, and thinks it the mouth; " if so, (says Mr. Ellis,) besides the office of supplying it with nourishment during the time of its mov-

“ ing about, it is the tube through which the
“ fine double filament proceeds, with which it
“ forms its delicate web, in order to accommo-
“ date itself in its torpid state, during its preg-
“ nancy, till the young ones creep out of its
“ body, shift for themselves, and form a new
“ generation.

“ In this torpid state the legs and antennæ
“ grow no more, but the animal swells up to
“ an enormous size, in proportion to its minute
“ creeping state. The legs, antennæ, and pro-
“ boscis, are so small with respect to the rest of
“ the body, that they cannot be easily disco-
“ vered, without very good eyes or magnify-
“ ing glasses, so that to an indifferent eye
“ it looks full as much like a berry as an
“ animal.

“ As soon as the female is delivered of its
“ numerous progeny, it becomes a mere husk
“ and dies; so that great care is taken in Mex-
“ ico, where it is principally collected, to kill
“ the old ones while big with young, to prevent
“ the young ones escaping into life, and depriv-
“ ing them of that beautiful scarlet dye, so much
“ esteemed by all the world.”

It is proper here to observe, that there are two
sorts or varieties of cochineal; the best or do-
mesticated, which the Spaniards denominate
grana fina, or fine grain; and the wild, which
they call *grana sylvestra*. The former is nearly
twice as large as the latter, probably because its
nature has been improved by the favourable ef-
fects of human care, and of a more suitable
nourishment,

nourishment, derived solely from the cactus cochenillifer during many generations. But it is only from the wild cochineal, living naturally on some of the *opuntia*, in different parts of America, that the descriptions of Brown, Linnaeus, and Ellis, were taken. It must also be observed, that the grana sylvestra are not only smaller than the others, but that their bodies are covered by very fine white downy filaments, which they spin to defend themselves against cold, rain, &c. in their wild state; but which adding to their weight, whilst it yields no colour, contributes with other causes to render them less valuable.

In the month of January 1777, Mons. Thierry de Menonville left Port au Prince, in the island of St. Domingo, for the purpose of procuring some of the living cochineal insects in Mexico, and bringing them from thence, to be afterwards propagated in the French West-India islands: an enterprize, for the expence of which four thousand livres had been allotted by the government. He proceeded by the Havannah to La Vera Cruz, where he was informed that the finest cochineal insects were produced at Guaxaca, distant about seventy leagues. Pretending ill health, he obtained permission to use the baths of the river Magdalen; but instead of going thither, he proceeded through various difficulties and dangers, as fast as possible, to Guaxaca, where, after making his observations, and obtaining the requisite informations, he affected to believe that the cochineal insects were highly useful in composing an ointment for his pretended disorder (the gout), and therefore purchased

chased a quantity of nopals, covered with these insects, of the fine or domestic breed, and putting them into boxes with other plants, for their better concealment, he found means to get them away as botanic trifles, unworthy of notice; and being afterwards driven by a violent storm into the bay of Campeachy, he there found and added to his collection a living cactus, of a species which was capable of nourishing the fine domesticated cochineal; after which, departing for St. Domingo, he arrived safe, with all his acquisitions, on the 25th of September, (in the same year,) at Port au Prince, where he began immediately to form a plantation of nopals, and to take steps for propagating the two sorts or varieties of cochineal, I mean the domesticated or fine, and the sylvestra or wild, which last he found at St. Domingo, soon after his return, living naturally on the cactus pereskia. But unfortunately for this establishment, he died in the year 1780, through disappointment and vexation, at seeing his patriotic endeavours so little assisted, and his services so sparingly rewarded by the government. Mr. Thiery de Menonville's labours being thus terminated, the Royal Society of Arts and Sciences at Cape Francois, having collected his papers, composed from them a treatise on the cultivation of the nopals, and the breeding of cochineal, &c. of which Mr. Berthollet has given an extract in the fifth volume of the Annales de Chymie, together with an account of his own experiments, for ascertaining the effects of the grana sylvestra, produced at St. Domingo, compared with those from Mexico in dying.

From

From the observations of Mr. Thiery de Mehonville, it appears that there are two varieties of the nopal, or cactus cochenillifer, growing in Mexico, one called the True Nopal of the Garden of Mexico, and the other the Castilian Nopal, a name given to the last of these varieties on account of its singular beauty. It appears also that the wild cochineal, or grana sylvestra, when reared upon either of these varieties of the nopal, become almost as large as the fine or domesticated sort, and lose the greatest part of those fine downy filaments with which they are naturally covered, and which contribute to render them less valuable than the latter.

But besides the advantage of affording the most suitable nourishment to cochineal, the nopals have another of very great importance, where these insects are to be raised as objects of commerce; which is, that they are not beset with thorns or prickles, like most of the cacti, and particularly the opuntia, tuna, and pereskia, which by this circumstance render the insects nourished upon them almost inaccessible to any who might wish to collect them: Whilst the true nopal, and that of Castile, have none but soft inoffensive thorns, and the nourishment which they afford is at the same time so peculiarly well suited to the cochineal, and especially to the fine or domesticated sort, that these last, though they can subsist on some, will prosper on no other species of cactus; and indeed the wild sort, though found naturally upon several other species of opuntia, are at present raised chiefly on the nopals in Mexico. The young insects, whilst contained within the mother, appear to be all con-

nected *one after the other* by an umbilical cord to a common placenta, and in this order they are in due time brought forth as living animals, after breaking the membrane, in which they were at first probably contained as eggs. Being thus brought forth, they remain in a cluster under the mother's belly for two or three days, until disengaged from the umbilical cord; after which the females, for the only time of their lives, exercise their loco-motive faculties, by creeping to proper situations on the plant; and in doing this they are led by a wise instinct, to prefer the under-sides of the different branches or articulations, (as being most defended from wind and rain,) where each attaches herself, by inserting her little tubular proboscis or mouth into the bark, and thus remains fixed to the end of life. By this insertion the female draws out for her nourishment the colourless mucilaginous juice of the nopal, and soon becomes covered with a fine adhesive downy substance. The male acquires a similar covering, but quits it at the end of a month, and in the shape of a little scarlet fly, jumps and flutters about for the purpose of copulation; and having thereby secured a future progeny, he dies almost immediately after. But the female having other duties to perform, outlives the male another month; at the end of which she is ready to bring forth her young, and this is the precise time for gathering those which are not wanted for breeding, and this is done by pressing the dull blade of a knife between the under surface of a branch of the nopal, and the clusters of insects attached to it, which being thereby separated, fall upon cloths previously spread

spread on the ground to receive them, and a sufficient quantity being thus collected, they are dipped (inclosed in a linen cloth or bag) into boiling water, and suffered to remain in it so long as is necessary for killing them, but no longer, lest the water should extract some of their colour. This being done, they are thoroughly dried by spreading and exposing them to the rays of the sun, by which they shrink so as generally to lose about two-thirds of their former weight. This, which has been found to be the best method of drying the cochineal, is now generally practised, though others were formerly in use; such as ovens, flat baking stones heated, &c.

Mr. Thierry de Menonville describes the male of the domesticated or fine cochineal as perfectly similar to that of the wild in every respect, excepting its size; nor does there appear to be any considerable difference between the females of these two varieties. The domesticated female, instead of that downy covering which enables the wild to bear inclement seasons, is only covered by a fine white powder or farina, serving in some degree as a defence against rain and cold, but not enough to enable her to remain abroad like the wild insects during the rainy seasons, which occur twice in every year. When these approach, the domesticated insects are all gathered, excepting only those intended for breeding a future stock, and these are preserved by removing the nopals on which they are placed into situations where they are secured from wind and rain, or by raising frames over them, and covering them with thatch or matting, until the

the return of favourable weather; whereas the wild insects, being more hardy, as well as more prolific, when once placed upon the nopals, would not only perpetuate, but multiply themselves without any farther care to such a degree, as to exhaust and destroy the plants, were they not all collected at the end of every two months, and the nopals perfectly cleansed (by wiping them with wetted cloths) from the down and other animal impurities left on their branches. The nopals become fit to nourish the cochineal at the end of eighteen months from the time they were planted. The quantity of fine or domesticated cochineal which a single nopal can nourish, usually weighs a third more than it could nourish of the wild. These last have also the disadvantage of selling for a much less price, but in return they are gathered six times in each year, whilst the fine yield but three crops in the same space, their propagation being wholly suspended during the rainy seasons.

In Mexico it is thought necessary to keep the two sorts or varieties of cochineal separated, at the distance of about one hundred perches from each other, lest the males of the wild, impregnating the females of the other sort, should occasion a degeneration thereof; a circumstance which seems to indicate that both sorts originated from the same stock, and that the domesticated is only an amelioration of the wild cochineal, through the favourable effects of a more suitable nourishment, and of warm covering; and this is rendered the more probable, by Mr. Thiery de Menonville's observation, that the former are never found in the fields or forests of

Mexico, nor indeed any where, but in the gardens and plantations of those employed in rearing them. But if the present size, appearance, and habits, of the domestic cochineal, were those which naturally belong to the insect, it might be supposed capable of maintaining an independent existence, remote from the dwellings, and without the help of mankind, as it must have done before its properties were so well known, as to render it an object of human care and protection; and in that case, some of this sort of cochineal doubtless would have continued to subsist in their natural state, since the whole of a race, composed of so many minute individuals, could not have been taken and brought under the protection and dominion of man. Nor is it easy to explain why none of them ever are found in a wild state; but by supposing them to have been rendered effeminate by luxurious food, and by protection from inclement weather; and that consequently they have been enabled to lay aside their natural downy cloathing, as sheep lay aside their wool, when, after being removed to warm climates, they find it no longer necessary; and that their natural habits and means of self-preservation being lost, they are rendered incapable of subsisting without a continuance of the same fostering care which first occasioned their effeminacy; or if they ever do find means to subsist without it, they do so only by regaining their natural downy covering, and by returning again to their primitive habits, so as not to be any longer distinguishable from those who were never out of the wild state,

After

After the death of Mr. Thiery de Menonville, the stock of fine or domesticated cochineal, which he had multiplied in the garden at Port au Prince, was suffered to perish by neglect; but the hardier wild sort, having found means to subsist, though neglected, was afterwards taken under the care of Mr. Bruley, (substitute of the attorney-general of that province,) who, from the remains of Mr. de Menonville's establishment, formed a plantation for propagating and multiplying these insects, of which he sent a considerable quantity, in the year 1787, to the minister of the French marine at Paris; at whose request the Royal Academy of Sciences commissioned Mr. Berthollet, and three others of its members, to cause proper experiments to be made therewith, which they accordingly did, under their own inspection, at the celebrated establishment (for scarlet dying) of the Gobelins near Paris; and from these experiments it appeared, that the grana sylvestra of St. Domingo afforded colours by dying exactly similar to those of the Spanish fine cochineal, allowing only after the rate of twelve ounces of the former for five of the latter. Mr. Bruley some time after sent to France a second parcel of the same cochineal, produced from his plantation in the year 1788; and this being tried by the same commissaries of the Royal Academy, though in different ways, produced nearly the same effects.

Very considerable differences of external colour or appearance occur in different parcels of the fine cochineal; probably because the white
farina-

farinaceous powder, with which these insects are naturally covered, is more or less washed off by the hot water in which they are killed by immersion, as well as by other circumstances which occur in the drying and packing. When this powder has been intirely removed, the insects appear of a chocolate colour, inclining a little to the purple; and are then called *renigrida*. Generally, however, so much of the white powder remains, especially in the little furrows which cross the insect's back, as occasions a grayish appearance, called *jaspeada*; and sometimes indeed this powder so perfectly covers the cochineal, as to render them all over white. This I remember to have been particularly the case of a parcel which a friend of mine had purchased, and which was refused by several dyers to whom it had been sent, from a persuasion of its having been fraudulently covered by white lead, or some other metallic calx intermixed with it, to increase the weight; and one very eminent dyer alleged, that he had formerly seen and tried a similar parcel, and that the white powder had been found to consist principally of a preparation of mercury. That I might be enabled to ascertain whether an opinion so unlikely had any foundation, my friend caused several ounces of this powder to be separated from the insects by sifting; and having tried it sufficiently, I found it to be intirely of an animal nature, and apparently nothing but the farina which naturally covers these insects. It even yielded a considerable portion of the true cochineal colour, and dyed good scarlets in the usual way, though it probably was assisted by some of the limbs or other parts of the bodies of the insects, separated

rated by rubbing in the sieve: though I am persuaded that a part of the colour in question naturally existed in the farina or white powder itself; and if this be the case, it would be highly advantageous to contrive means for killing the cochineal, without washing off any part of the powder in question, which might, I think, be done by putting them into tinned vessels, made so as to shut closely, which might be plunged into boiling water, and withdrawn at a proper time, without letting a single drop of it come into contact with the insects, or carrying off any of the powder in question. And perhaps this method might be used with advantage, even if it should be found that no colouring matter resides in the white powder, since it is difficult to conceive that the cochineal can be plunged into boiling water, so as to wash away the powder entirely, (as is frequently done,) without a loss of some part of the colouring matter contained in the bodies of the insects themselves.

The true original grana sylvestra seem to have been very different from what is at present sold under that denomination in this kingdom, and which has the appearance of a dry powder, with many small lumps or fragments of something which had been previously formed into a cake or a dried uniform mass. It affords indeed nearly the same species of colour as cochineal, but in a much smaller proportion; six pounds being necessary, according to my experiments, to dye as much cloth as one pound of the fine cochineal; whereas the true grana sylvestra are represented as yielding at least half as much as the fine, and they sell for at least half the price

price in some parts of Europe; whilst here the substance so called, and which has not the least appearance of any insect, sells at present for less than an eighth of the price of fine cochineal. Probably it is composed of the white downy substance which the wild insects are represented as leaving in great abundance on the nopals, and of other excrementitious matters deposited by them, joined to fragments, broken limbs, dust, &c. of the insects themselves, and perhaps with an addition of some vegetable matters, all beat up into one uniform mass. Something of this sort was formerly practised even with the true cochineal, according to Dr. Brown, who says, "the cochineal insects used to be prepared by
 "pounding them, and steeping the pulp in the
 "decoction of the texuatla, (a species of me-
 "lastoma, as he supposes,) or that of some
 "other plants, which they observed to heighten
 "the colour. This, continues Dr. Brown, was
 "left to settle at leisure, and afterwards made
 "into cakes and dried for the market." Probably the true *grana sylvestra* are what are sold in this country under the name of *Granillo*, which appears, as the name indeed imports, to consist of insects somewhat smaller than those composing the fine cochineal, and therefore in that respect answers to the best authenticated descriptions of the wild cochineal.

It had been generally believed that the cochineal derived its colour from the red or crimson fruit of the nopals, and other species of *opuntia*; and I was formerly induced by this opinion to make various trials with the fruit of the cactus *opuntia* for dying, instead of cochineal.

neal. They all indeed proved unsuccessful; and I attributed this want of success to their want of that kind of animalization, which the vegetable red colour was supposed to receive when eaten and assimilated by the insect; and I thought it probable, as indeed others have done, that many vegetable colouring matters might be equally improved in the same way, and that perhaps, instead of insects, it might be advantageous to employ large animals for this purpose*. It is, however, now certain, from the observations of Mr. Thiery de Menonville, and from other well-attested relations, that the cochineal insects do not feed on the red fruit of the cactus, but upon its branches or articulations to which they adhere, and which contain nothing like a red juice; and that they sometimes live, propagate, and preserve their colour on those species of cactus which do not bear red-coloured fruits:

* Dr. Garden relates, that a negro woman in South Carolina, who then gave suck, having eaten six of the red fruit of the prickly pear, (*Cactus Opuntia*,) and some of her milk being collected and left until the cream had separated, this last was found to be of a reddish colour, considerably weaker indeed than the lively red which the urine was found to acquire by the same fruit. He found also, that after cows had been feeding in an indigo field, not only their urine, but the cream of their milk, "was of a most beautiful blue colour;" from whence he concludes, that the indigo blue colour resides in the oily part of the plant. See *Philosoph. Transf.* vol. 50. p. 269.—And in the third vol. of the same Transactions, mention is made of a berry growing in Bermudas, and called the "Summer Island Red-weed," which berry is as red as the prickly pear, and giving "much the like tincture; out of which berry cometh out first worms, which afterwards turn into flies, (somewhat bigger than the cochineal fly,) feeding on the same berry, in which there hath been found a colour no whit inferior to the cochineal fly."

consc-

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consequently the colour of these insects does not result from that of their food, but from their particular constitution and properties.

The very great demand for cochineal, almost immediately after it had been made known in Europe, caused a very rapid multiplication of it in the Spanish American settlements. It appears from Acosta's statement, that so early as the year 1587, there came to Spain, by a single flota, no less than 5670 arobas of fine cochineal, which, at the rate of 25lb. each, weighed 141,750 pounds; and the common annual importation, as stated some years since by the Abbé Raynal, amounted to 4000 quintals, or 400,000lb. weight of the fine cochineal, 300 quintals of the grana sylvestra, 200 ditto of granillo, and 100 of cochineal dust, which were computed to have sold for a sum equivalent to about nine millions of French livres; without reckoning considerable quantities sent directly from America to the Philippine islands, for supplying a considerable part of Asia. The European importations have, however, been considerably increased, during several of the last years. Since, according to very good information, which I have received, the quantities of fine cochineal brought to Spain in the years 1788, 1789, and 1790, amounted to eleven thousand bags, weighing 200lb. each, and making together 2,200,000lb. weight; and between the 1st of January 1791, and the 1st of October in the same year, the importations had exceeded 2000 bags.

It must, however, be observed, that the importations during these years were somewhat greater than usual, because an advance in the price of cochineal in Europe had induced the holders of it in America to send their stocks more speedily to market, in order to avail themselves of the higher prices; and, from accurate calculations, I think it may be concluded, that the average quantity of fine cochineal annually consumed in Europe amounts to about three thousand bags, or 600,000 lb. weight, of which about 1200 bags, or 240,000 lb. weight, may be considered as the present annual consumption of Great Britain. A greater quantity comes indeed into the kingdom, but the surplus is again exported to other countries. These 1200 bags may be supposed to cost 180,000 l. sterling, valued at 15s. per lb. which has been about the average price for some years past. According to Don Antonio Ulloa, the greatest quantities of cochineal are produced at Oaxaca, Tlascala, Chulula, Neuva Galicia, and Chiapa, in New Spain, and at Hambatio, Loja, and Tucuman, in Peru.

About six years ago Dr. James Anderson, physician-general on the company's establishment at Madras, persuaded himself that he had found the true cochineal insects subsisting naturally on a species of salt grass in that part of India; and some parcels of a dried insect, probably of the coccus kind, (but more like the kermes,) which he mistook for the true coccus cacti, were sent by him to this country; of which I made several trials, at the request of a friend, (as others also did,)

did,) and found them to be neither of the same species, nor possessed in any degree of that particular colouring matter for which the cochineal insect is so highly valued; though in their dried state they had nearly the same external appearance, excepting their size, which was considerably less than that of the true Mexican cochineal; but upon rubbing them in a mortar, I soon perceived, that instead of breaking into a dry powder like cochineal, they could only be beat into a kind of unctuous paste; nor would any degree of drying, short of combustion, overcome this unctuous quality, or render them capable of being rubbed into the form of a powder; and in point of colour there was a more essential difference, since they produced nothing better than a chocolate brown, by the means usually employed for dying scarlet with cochineal, nor indeed by any other means. This chocolate colour proved indeed sufficiently durable on wool, but it may be dyed so cheaply by other matters, and indeed these insects yielded so little of it, that they never can be worth collecting as a dying drug*.

It occurred to me, however, on this occasion, that though Dr. Anderson had failed in his expectation of finding the cochineal in a country

* The Company, in their letter of the 31st of July 1787, to the government of Madras, were pleased, from very laudable motives, to direct, that every further pursuit respecting this species of insects "should be effectually discouraged," because "were it to fall into the hands of improper persons, it might be made use of to mix with and adulterate the real cochineal, to the great injury of the consumer, as it would most assuredly spoil the beauty of every scarlet done therewith."

where it probably never existed, (the genus of plants on which it is alone fitted and destined to live having been originally produced only in America,) yet it would not be very difficult to convey both the insects, and the cactus cochecillifer (their natural food and habitation) to the East Indies, and there propagate both, so as in a few years to obtain from thence ample supplies of a drug so highly important in a great manufacturing country, and for which nearly 200,000*l.* sterling are annually paid by this to the Spanish nation, especially as great advantages in this respect would result from the cheapness of labour and subsistence in the East Indies; and considering moreover how much the quality of the indigo of that country had been improved, and the quantity increased within a few years, through the measures taken so opportunely for these purposes by the East-India Company, at a time when the usual supplies of that article from other countries had been greatly diminished.

Similar ideas on this subject occurred, or were suggested, to the Directors of the East-India Company, who in the spring of the year 1788 procured from his majesty's botanic garden at Kew (through Sir J. Banks, Bart. P. R. S.), some of the true nopal plants, two of which were sent out by the Bridgwater, during that season, to Madras, and put under the care of Dr. Anderson, where they have since been multiplied to several thousands, and been transplanted from thence to Bengal and St. Helena, in order that a sufficient stock might be in readiness to receive any cochineal insects which should

should arrive; a committee of the Directors having previously reported as "their opinion, " that it be recommended to the Committee of " Correspondence to take such measures as they " they shall judge best suited for procuring " from America a quantity of the cochineal " insect, with a view to the introduction of the " same upon the coast of Coromandel." Unfortunately, however, it does not appear that any measures have yet been effectual in procuring the domesticated insect, or even the sylvestra, though this last exists in Jamaica, (as does the true nopal,) and in many other accessible parts of America, and probably in more than ordinary perfection in Brazil; at least I made trial about the year 1787 of some which had been sent from thence by the way of Lisbon, and which yielded *full* as much colour, and of as much beauty, as half its weight of the *very best fine cochineal*; and until this last can be obtained, would it not be advisable to make trial of the other, which, by being properly nursed, and nourished upon the true nopals, might perhaps in a little time improve so as to supersede the necessity of seeking any farther?

C H A P. XI.

Of the Properties and Uses of Cochineal; with an Account of new Observations and Experiments calculated to improve the Scarlet Dye.

“ Le travail a été mien, le profit en soit au lecteur.”

JEAN REY.

IN the English translation of Clavigero's History of Mexico, the ancient inhabitants of that country are said to have obtained a *purple* colour from cochineal. Probably, however, either the author or translator of that work has mistaken purple for crimson; this last being the *natural* colour of cochineal, and what it always affords with the aluminous basis, which Clavigero, in another part of his history, says, the Mexicans had been used to employ in early times; though it certainly is difficult to understand how they could have become acquainted with it. This account moreover accords with that of Herrera, who, after mentioning the Tuna or Nopal of Tlaxcalla, says, “Optimum
“longè granum dat Tlaxcallum cujus indigenæ
“prestantissimam tincturam ex illo conficiunt,
“hoc modo, comminuunt & macerant in de-
“cocto *aluminis*, & ubi refederit, cogunt in ta-
“bellas, quas Hispani vocant *grana en pan*.”

There is also reason to conclude, that during a number of years none but the aluminous basis was used for dying with cochineal in Europe,
until

until an opportunity had been accidentally afforded to Kuster, Kuffler, or Kepfler, a German chymist, of seeing the wonderful effects of a solution of tin, by nitric acid, in exalting the colour of this drug, which led to a discovery of that most vivid of colours, the cochineal scarlet. Kuster brought his secret to London about the year 1543, and the first establishment for carrying it into practice seems to have been made at Bow, from whence scarlet was called the Bow dye in this country. Some writers, and among them Mr. Macquer, have ascribed this discovery to *Drebel*, a Dutch chymist*; but Kunckel, and others, who have attributed it to Kuster, appear to have done it on better grounds. Probably Drebel obtained a knowledge of it very

* Mr. Macquer, in a Memoire, printed among those of the Academy of Sciences of Paris for 1768, says, “*Drebel, chimiste Hollandois, a imaginé d’employer dans la teinture de cochenille, de la dissolution d’étain faite par l’eau regale, & des lors on a obtenu le plus vif & le plus celatant de tous les rouges dont l’art, & meme la nature nous ait donné l’idée; je veux dire l’ecarlate couleur de feu, qui a porté d’abord le nom d’ecarlate de Hollande, parceque c’est dans ce pays que les premieres manufactures ont été établies,*” &c.

Mr. Macquer seems also mistaken in supposing that the first solutions of tin employed in this way were nitro-muriatic, or made with aqua regia, there being very good reason to believe, that aqua-fortis alone was used for some years for this purpose.

Mr. Delaval inclines to carry the first use of tin for dying, back to very remote antiquity; and thinks the Phenicians used that which they were said to have brought from Britain in this way, because (as he erroneously asserts) “this is necessary to the production of red colours, whether from animal or vegetable materials.” See Experimental Enquiry, &c.

soon after the discovery was made, and that in consequence thereof scarlet dying was very early practised in Holland; as it was also in France, by the famous Gobelins, who received an account of the process from Kloeck, a Flemish painter, to whom it had been communicated by Kuster himself. As the name of scarlet had, until that time, been invariably given to the fine reds dyed with kermes, the *fiery* cochineal colour, which in England was distinguished as the Bow dye, obtained in other parts of Europe the name of Dutch Scarlet, Scarlet of the Gobelins, &c.

It has been generally supposed, that after the effects of tin upon the cochineal colour had been discovered, as before mentioned, nothing more was wanting to produce what is at present called scarlet, than to apply the colour so produced as a dye to wool; or, in other words, that a nitric, or nitro-muriatic solution of tin, was sufficient to change the natural crimson of cochineal to a scarlet. Such at least has been the opinion of every writer on the subject until the present hour; though it will hereafter be proved to have been an erroneous opinion, and that the nitric solution of tin invariably produces (with cochineal) a crimson or rose colour, and not a scarlet, unless other means be also employed to incline the cochineal colour so far as may be necessary towards the yellow hue; and the means of doing this seem to have been stumbled upon, and continually employed without any knowledge of their true effect. I have already mentioned that tartar is, and for many ages appears to have been, generally employed with
alum,

alum, to compose the ordinary boiling liquor or mordant for woollen cloths; and it seems probable, that when the first attempts were made to employ the solution of tin, instead of alum, it would naturally have been imagined, that as tartar had been found useful with the latter, it must also produce good effects with the former, and that a trial of it having been thus produced, and the most brilliant of all colours having been found to result from this combination of tartar with the solution of tin, their joint use was afterwards continued, without any inquiry concerning the particular share which either of them had in producing such pleasing effects.

At first indeed a diluted nitric acid appears to have been employed for dissolving the tin without any admixture of the muriatic; but as the former would have held but a small portion of the calx of that metal in a state of suspension, and as even that portion would have been liable to precipitate in a few days, the practice of adding either a little sal-ammoniac, or a little sea salt, to the aqua-fortis, and of thereby producing an aqua regia, or nitro-muriatic acid, seems to have been introduced, though it did not become general until a considerable time after; since Hellot gives an account of the process used in his time for dying scarlet at Carcassonne, in which tin was dissolved *only* by diluted aqua-fortis; and he mentions the late Mr. Baron, as claiming the merit of having been the first in that city who employed an aqua regia for dissolving tin, *in order to prevent a precipitation of its calx or oxide*; and even when this was done, the sal ammoniac and sea salt were added but very

very sparingly, from a belief, which still subsists universally, that a more liberal use of either of them in this way, or of the muriatic acid in their stead, would render the cochineal colour a crimson instead of the scarlet, which last is supposed to be a peculiar production of the nitrate of tin; though nothing can be more groundless than this belief; since the nitrate, and the muriate of tin, both *equally* afford a crimson colour with cochineal, and neither affords a scarlet without the aid of other means.

The dyers' ordinary solution of tin is made with that species of nitric acid, called single aqua-fortis, and which, as usually prepared, is capable of dissolving about one-eighth of its weight of tin, grained or granulated, by pouring it, when melted, into water, briskly agitated with a bundle of rods, or by other suitable means.

For each pound of aqua-fortis, it is usual to add after the rate of from one to two ounces of sea salt, though some prefer the muriate of ammoniac (sal ammoniac) for this purpose. A little water is moreover commonly added, in order still farther to dilute the acid, and moderate its action on the tin. Those solutions of it which were made most slowly, and with the least separation of fumes or vapours, have been found to succeed the best; probably because in these the tin is less calcined, and the solution retains a larger portion of azote than in those which proceed more rapidly. It is usual to allot after the rate of two ounces of grained tin to every pound of aqua-fortis; and the metal

tal should be put into it at different times, waiting until one part is nearly dissolved, before another is added, lest too much heat should be evolved, and the solution proceed too rapidly; though there is no danger of this, in the latter part of the process, which indeed should be protracted so as to last two or three days. The water mixed with the aqua-fortis should be ascertained by weighing or measuring, in order that a proper allowance may be made for it in calculating the strength of the solution, or the weight of metal contained in a given quantity thereof, which, supposing half as much water as of aqua-fortis to have been used, will be about one-thirteenth part of the whole; and when the solution (which the dyers in this country generally call *spirit*) has been made in these proportions, about eighteen or twenty pounds of it will be wanted to dye a full cochineal scarlet, upon one hundred pounds weight of woollen cloth, though but little more than half of this quantity is usually employed in the first preparation, or boiling part of the process; for which, supposing one hundred pounds weight of cloth are intended to be died, eight or ten pounds of tartar or argol are put into a suitable dying vessel, (of pure block tin,) with a sufficient quantity of clean soft water *, and six or eight ounces of powdered cochineal. Immediately after this, ten or twelve pounds of the solution of tin, prepared as before mentioned, are to be added; and when the mixture is nearly ready to boil,

* Hard water tends to produce a rose colour, which the dyers commonly endeavour to obviate, by boiling bran or starch in their water.

the cloth being first thoroughly moistened, (that the dye may penetrate and apply itself equally thereto,) is put into the dying liquor, and turned through it (by the winch) a few times very quickly at first, and afterwards more slowly, whilst the liquor continues to boil, for the space of an hour and a half or more, after which it is to be taken out, and rinsed in clean water. By this *first boiling* or preparation, the cloth will have acquired a flesh colour. For the *second*, or dying process, the tin vessel is replenished with clean water, and when this appears almost ready to boil, five, or if a *full* colour be wanted, six pounds of cochineal in powder are to be put into it, and well mixed, by stirring for a few minutes; after which, the remaining part of the solution of tin is to be added, and the whole being well stirred, the cloth is to be put into the liquor, and turned *very briskly* through it, over the winch, for a little time, in order that both ends may receive an equal portion of the dye; after which it may be turned more slowly for the space of half an hour, or until the dying liquor becomes exhausted, when the cloth is to be taken out, aired, and rinsed.

An ounce of fine cochineal is generally deemed necessary for dying a pound of cloth; but something less than this portion is frequently made to answer, especially for coarser cloths.

It is by no means necessary to follow this (which is the usual) process for dying scarlet. I have often given that colour very well at one single boiling, (without any preparation,) by
mixing

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mixing the whole quantity of tartar, solution of tin, and cochineal together; for such, in this case, is the attraction of wool for the colouring matter, as well as for the oxide of tin, that it will take up both very freely, and retain them permanently when thus mixed. I think, however, that in this way the cloth does not exhaust the colour of the dying liquor quite so perfectly as in the other; which seems also to be the case, where, instead of emptying out the boiling liquor after the first preparation, the remainder of the solution of tin and the cochineal are added to it, and the cloth is dyed therein; and as far as I can judge, there is no other reason for incurring so much expence of fuel, labour, and time, than this, which indeed is not a sufficient reason, where there are other cloths to be dyed of similar colours immediately afterwards; because what may have been left by the first, will naturally be gained by those which are afterwards dyed in the same vessel.

I have moreover often dyed very beautiful scarlets, by preparing or boiling the cloth with the *whole* quantity of solution of tin and tartar at once, (as is commonly done with alum and tartar,) and afterwards dying it unrinsed with the whole of the cochineal in clean water only; and in this way I have found the colouring particles so completely taken up by the cloth, that the liquor became as clear as the purest water, and the colour was generally very perfect.

Some dyers, besides the tartar used in the first boiling, employ as much of it as of cochineal in the second or dying part of the process; and
certainly

certainly the doing so will be advantageous, whenever the colour is wanted to approach nearer than ordinary to the aurora complexion, though this is not the effect which would be generally expected to result from thence. Pœrner uses no cochineal in the first boiling, nor indeed is any necessary, though a little may probably help to decompose the oxide of tin, and fix it more copiously in the fibres of the cloth. For scarlet, many dyers prefer the red argol or crudered tartar; but the matter to which it owes this colour is wholly incapable of adding any colour to that which the wool may otherways acquire, and therefore at best it will only prove useless. Wool is seldom dyed scarlet until it has been spun, wove, and fulled; because the yellowish tendency which the cochineal colour acquires from tartar in the dying process, is nearly all taken away in the fulling, and a *rose* produced instead of a scarlet colour.

Mr. Berthollet thinks the solution of tin, before described, does not affect the cochineal colours, *merely* by the proportion of that metal, which it contains; and that when either sal ammoniac, salt-petre, or common salt, enter the composition of an aqua regia, the compound will be less acid than when it consists of the nitric and muriatic acids solely; and that the former deserves therefore to be preferred, as having a less violent action upon the fibres of woollen cloths, and upon colouring matters.

It is remarkable, that during the present century, no considerable improvement has been made in the process or means of dying scarlet;
a cir-

a circumstance which is the more extraordinary, since the pre-eminent lustre, as well as the costly nature of this dye, have rendered it an object of particular attention, not only to dyers, but to eminent chymists, by whose researches we might have expected, that at least every obvious improvement therein would have been long since attained. That this, however, has not been done, will, I think, manifestly appear, by the following statement of my own particular observations and experiments on this subject, which began in the year 1786. Having been led to pour boiling water repeatedly upon powdered cochineal in a china basin, and to decant it as often from the subsiding insoluble parts, until they would yield no more colour, I found that by adding a little pot-ash to this seemingly exhausted sediment, and pouring fresh boiling water thereon, a farther copious extraction of colour instantly displayed itself, equal, as far as I could judge, to about one-eighth of the whole of that which had been originally contained in the powdered insects; and having by repeated trials constantly found this effect, I too hastily concluded that the colour thus obtained by the help of pot-ash was so far of a resinous nature, or so intermixed with a resinous matter, as to have always been incapable of being extracted by the means usually employed for dying with cochineal; and that if it should be found capable of yielding colours as beautiful and permanent as those dyed with the more soluble colouring particles of these insects, an acquisition might be made of so much *new* colouring matter, which till then had, as I conceived, been

always thrown away. That it was capable of yielding such colours, I soon ascertained, by repeatedly extracting this particular colouring matter by the help of pot-ash, and afterwards dying small pieces of cloth scarlet with it, (in the ways usually employed for dying that colour,) and by comparing and exposing them to the weather with other pieces dyed from the more soluble colouring matter of cochineal.

Continuing my inquiries on this subject, I soon perceived that the colour, denominated scarlet, must in fact be a compound colour, (like green, purple, and orange,) consisting probably of about three-fourths of a most lively pure crimson or rose colour, and about one-fourth of a pure bright yellow; and that therefore when the natural crimson of the cochineal is made scarlet by the means always hitherto employed for dying that colour, there must be a *change* produced equivalent to a conversion of one-fourth of the cochineal colouring matter from its natural crimson to the yellow colour; and as a better yellow might be obtained from other drugs, where it naturally exists, and for a fiftieth part of what it costs when obtained in this way, from the *most costly of all dying drugs*, (cochineal,) it necessarily followed, that this, the universal and only known method of producing a scarlet, must be highly injudicious, because unnecessarily expensive.

Convinced of this important truth, and at the same time believing too easily, on the authority of Hellot, Macquer, and others, that the natural

natural crimson of cochineal was rendered scarlet only by the nitric acid employed to dissolve the tin used in dying that colour, I began a series of experiments for producing it, without any such waste of the cochineal colouring matter. For this purpose it seemed necessary to discover a mordant or basis, capable of permanently fixing and strongly reflecting the pure vivid cochineal crimson, without giving it any tendency towards the yellowish hue. I concluded, and found by experiments, that the necessary *purity* and *vivacity* of colour could not be obtained from an aluminous basis, however dissolved, though it doubtless fixes the colouring particles of cochineal more durably than any other mordant; and the like defect was found to accompany the solutions of all the other earths, as well as of the metals and semi-metals, tin alone excepted; and with this farther disadvantage, that most of them either degraded or altered the natural colour of cochineal very considerably. It followed therefore that a basis to suit my purpose must be sought for in the pure white calx of tin, so dissolved or combined as to reflect the cochineal crimson unchanged, and with the greatest possible lustre. Misled by what those eminent writers Dufay, Hellot, Macquer, Scheffer, le Pileur d'Apligny, &c. had advanced, as well as by the opinions of others, with whom I had conversed on this subject, I erroneously concluded, that all solutions of tin, in which the nitric acid predominated, would necessarily incline the cochineal crimson towards the yellowish hue, and that therefore such solutions ought to be excluded from my experiments. In this

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persuasion, I dissolved parcels of that metal in almost every other acid, and tried them separately for dying with cochineal. Their several effects will hereafter be more particularly stated: at present I need only mention, that of all others the muriatic solution seemed the best suited to answer my purpose, as it both fixed and reflected the pure crimson or rose colour of the cochineal unchanged, and with the utmost brightness. To produce a scarlet, therefore, it was only necessary to superadd, and intimately combine with this crimson or rose colour, a suitable portion of a lively golden yellow, capable of being properly fixed and reflected by the same basis. Such a yellow I had previously discovered in the *Quercitron* bark, (which will be the subject of my next chapter,) and also in what is here called young fustic, (*Rhus Cotinus*, Lin.) though its colour was much less bright, and much less durable, than that of the *Quercitron* bark; two samples of each, dyed by the same means, having been alike exposed to the weather at the same time, the fustic colour was nearly destroyed, before that of the bark had sensibly faded. This last had also the advantage of being not only the brightest, but the cheapest of all yellows, since one pound of the bark in powder, which cost but three-pence farthing, dyed, with a sufficient quantity of muriate of tin, between thirty and forty pounds weight of woollen cloth of a full bright golden yellow; and this being afterwards dyed in the same liquor, with one-fourth less of cochineal than what is usually employed, acquired a scarlet equal in beauty and durability to any which is

usually given by the ordinary means, with a full proportion of cochineal; and such were the general results of a great number of experiments.

The quantity of muriatic solution of tin necessary to dye a given quantity of scarlet in this way, seemed to me at that time to depend on the proportion of metal contained in it, and this last to depend on the strength of the acid used for that purpose. That which I employed, and which I bought at the price of 38s. per 112lb. or about four-pence per pound, dissolved in a strong sand heat, one-third of its weight of granulated tin; and this solution would, with the proportions of cochineal and bark before mentioned, dye about ten times its weight of cloth, of a good scarlet colour.

I have said that three pounds of muriatic acid, which cost but one shilling, might be made to dissolve a pound of tin, which would require eight pounds of single aqua-fortis to dissolve it; and this quantity of aqua-fortis, at the rate of 8d. per lb. would cost 5s. 4d., so that on each pound of tin dissolved by muriatic acid, instead of the nitric, I calculated a saving of 4s. 4d. The muriatic acid, therefore, which M. Beaumé had stiled the true dissolvent of tin, ("Le vrai dissolvant de l'Etain,") seemed also to be of all others the cheapest; and with this farther advantage, that a solution made by it was as transparent and colourless as the purest water, and capable of being preserved for many years, without the least alteration, whilst the dyers' nitro muriatic solution of tin or spirit becomes

turbid or gelatinous very speedily, and even in a very few days, if the weather be warm.

I may add also, that the muriatic solution of tin seemed to exalt the colours both of the Quercitron bark and of cochineal, more than any other.

I perceived moreover another advantage resulting from this new method of dying scarlet, by a saving of all the tartar employed in the old. Before I began my experiments on this subject, I had endeavoured to learn the purpose which tartar was intended to answer in the usual process for dying scarlet; but having obtained no satisfactory answer on this point, I doubted of its producing any good effect, and therefore omitted it in my first trials; and as they succeeded, I also omitted it in all the others.

By these facts and ideas, I was led to believe that I had made discoveries likely to produce very important national benefits; and I particularly calculated in the first instance a gain of about $12\frac{1}{2}$ per cent. upon the whole quantity of cochineal consumed in Great Britain, by that part of its colouring matter which I proposed to extract by the help of pot-ash, and which I supposed to have been before always lost.

Besides this, I computed that a saving of 25 per cent. upon all the cochineal used in Great Britain for dying scarlet, aurora, and orange colours, would result from my plan of obtaining from the Quercitron bark so much yellow as was required for the composition of those colours

lours with the cochineal crimson, instead of converting any part of this last more costly colour into a yellow. And lastly, I calculated other savings, equal at least to 20,000*l.* annually, in the article of tartar, and in what the muriatic solution of tin was likely to cost less than that which is commonly used for the purposes in question.

With this opinion of the importance of my discoveries on this subject, I gave an account of them, as well as of an improvement in the black dye, (which will be hereafter explained,) to the Right Honourable the Lords of the Committee of his Majesty's Privy Council, appointed for the consideration of all matters of trade, &c. and their lordships, with a laudable solicitude for the public welfare, were pleased, by an order bearing date at Whitehall, the 18th of September 1787, to refer the same to "six capital dyers," named in the said order, who were "desired to inquire into the facts respecting the said important discoveries in the black and scarlet dyes;" and afterwards "to report to the committee their opinion of the merits and utility" thereof.

It was not, however, until the 22d of January following that an experiment relating to the scarlet dye was made at the dye-house of Messrs. Goodwin, Platt, and Co. Bankside, Southwark.—Considering on that occasion how much practical operators, in all the arts, are inclined to distrust improvements offered by speculative men upon the grounds of theory or

philosophical reasoning, I was desirous of making my first trial, under the most favourable circumstances, in order that by its signal success I might effectually obviate the effect of any unfavourable prepossessions in the minds of those who were to report on the merits of my discoveries. For this purpose I prepared a large quantity (near 100 lb.) of the muriatic solution of tin; and in order that the acid might be perfectly saturated with the metal, I added an over proportion of the latter, and kept both at the boiling point, by means of a sand heat, for the space of three days and nights. In this way I obtained a solution perfectly colourless, of a very pungent smell, and so highly volatile, that like æther it was almost impossible to prevent its escape from the vessels in which it was contained, however closely stopped. The acid had in this instance dissolved as much tin as it was capable of doing; but this complete saturation, instead of proving beneficial, as I had expected, became an obstacle to my success.

Two pieces of long baize, weighing together 188 lb. had been chosen as the objects of this experiment. I had before observed, in my private trials, that the colour generally proved most lively when given with a full proportion of the muriate of tin; and also that the colouring matter of the cochineal was most completely imbibed and *taken up* out of the dying liquor by the cloth, when the whole portion of the solution of tin, instead of being applied at different times, was boiled up at once with the Quercitron bark; an effect the more desirable for me, because

cause I intended to employ a very small proportion of cochineal, and therefore wished to leave as little as possible of its colouring matter behind, floating in the dying liquor, especially as it would be difficult properly to estimate the exact quantity remaining therein.

For these reasons, I took a large portion of the solution of tin, *i. e.* 16lb. weight for the two pieces of baize, and threw the whole of it at once, with five pounds of powdered Quercitron bark, into a suitable tin vessel, properly filled with water a little warmed, into which the pieces of baize (previously moistened) were soon after put, and turned as usual over a winch through the liquor (which was made to boil) for the space of an hour, when they were both taken out, and rinsed in clean water, the dying vessel being at the same time emptied, and then filled again with warm water for the remaining part of the operation. The baize had, in this first boiling, acquired a very bright golden yellow, though but about one-fortieth part of its weight of bark was employed; and I had expected, from what had before happened in my own particular experiments, that it would have been so fully impregnated by the metallic basis, as to want no farther addition of the muriate of tin in the second part of the process. To secure myself, however, against a disappointment on this point, I cut off a bit from one of the pieces, and boiling it in a small pipkin with water, and a little cochineal, I saw with great concern that the fibres of the cloth were very far from having imbibed enough of the calx of tin to fix and raise the cochineal colour; and that a farther

portion of the solution would be absolutely necessary for this purpose. My disappointment in this respect appeared by subsequent experiments to have arisen from my having pushed the solution of tin (whilst making it) on to that point of complete saturation at which the muriatic acid and the metal combine most closely, and are decomposed with the greatest difficulty, which had been manifestly the case in this instance; because the water into which the solution of tin was poured in the dying vessel did not decompose any part of it, or become in the slightest degree turbid, as it does with other solutions of that metal; and the attraction of the woollen cloth was much too feeble to separate and attach to itself any part of the calx of tin, excepting only that which united with the colouring matter of the bark, and by this additional affinity became fixed in the wool as the basis of that golden yellow which it had received, as already mentioned; whilst the other and greater part of the calx remained in the water, (combined with the muriatic acid,) and was thrown away with it after the first boiling, but unfortunately not without having previously weakened the fibres of the wool by its corrosive property, of which I had then no suspicion, though it became manifest in the second part of the operation. For this, five pounds of cochineal were put into the dying vessel, with six pounds more of the muriate of tin, and being well mixed in the water, the two pieces of baize were put into the liquor, and dyed therein for about fifteen minutes, when the colour not seeming to rise properly, four pounds more of the solution of tin, and one pound of cochineal, were added;

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added; and the dying was continued, until it appeared soon after that the texture of the cloth was greatly injured by the muriate of tin, which seemed in this, as well as in subsequent trials, to have a much stronger and more corrosive action upon the fibres of wool than other solutions of that metal, though before that time I had always been persuaded that it would on the contrary have acted more mildly in this respect than the ordinary dyers' solution or spirit; and indeed I had been led to this persuasion by the concurrent opinions of several very eminent chymists, who had all represented the nitric acid as exerting a stronger and more corrosive action than the muriatic upon animal substances. Even that most excellent chymist Berthollet has observed, in the tenth volume of the *Ann. de Chymie*, published so lately as the month of August 1791, and after he had been particularly employed in examining the effects of the different acids upon wool and silk, that "*l'acide sulfurique & l'acide muriatique exercent une action moins vive, sur les substances animales que l'acide nitrique suffizamment concentré.*" And this doubtless is true of these acids acting merely as acids; but very different properties appear to result from their combinations with metals, and metallic substances; among which, the metallic solutions by muriatic acid seem generally more corrosive than those made by any other. This is particularly true of the muriates of mercury, silver, lead, bismuth, and antimony, as well as that of tin; but the corrosive nature of this last, and the difficulty of decomposing it, seem to be increased, in proportion

tion as the muriatic acid is more completely saturated or combined with a greater portion of the metal. It is indeed true, that the proportion of solution of tin used in the foregoing experiment, was much greater than I had ever before employed, as it amounted to 26 lb., and contained above six pounds of the metal, which is four times as much as would suffice (dissolved by a mixture to be hereafter explained) for the same weight of cloth. But still I am persuaded, that an equal quantity of any other solution of tin would not have injured the like quantity of cloth in an equal degree, and being thus made sensible of the danger that must attend the use of a mordant so corrosive, I was convinced of the expediency of searching for one more harmless in this respect, though it certainly is very possible, with proper care, to employ the muriate of tin (containing a smaller proportion of the metal) so as to produce all the good effects which I had expected from it, without any injury to the cloth, as I have found by a multitude of experiments since, as well as before, that of the 22d of January 1787.

From whence this corrosive property of the muriate of tin arises, may become a subject of future inquiry. At present I shall only observe, that in some experiments which I made, with the hope of correcting it, I constantly found this saturated and highly corrosive muriate of tin possessing a strong attraction for oxygene, and that by absorbing it, as it did from various matters, this corrosive property was always greatly diminished. This led me to oxygenate the

the muriatic solution of tin, by putting a little manganese into it, or rather by dissolving tin with a little manganese in muriatic acid; but though the solution made in this way was evidently much less corrosive, it contained a small portion of the manganese which darkened the cochineal colour, making it incline towards a purple; and this defect, though in a much less degree, accompanied the solution of tin made by the oxygenated muriatic acid, as prepared for bleaching.

I afterwards oxygenated the muriatic acid, by mixing it with about one-third less than its own weight of the nitric, and with this I made a solution of tin; which appearing to be no more corrosive than the common dyers' spirit, and not changing the cochineal crimson towards the yellow hue, I was hastily induced to venture with it upon another trial at the dye-house of Messrs. Goodwin and Co. a few weeks after the first. It was, however, made only on one piece of baize, weighing about ninety pounds, which I caused to be boiled with about eight pounds of this murio-nitric solution of tin, and two pounds and one-half of powdered Quercitron bark. This mordant, however, acted very feebly, or rather failed, in exalting the yellow colour of the bark, which took but very slowly on the baize, and never rose much higher than a straw colour, even after two hours boiling; when a considerable quantity of yellow colour, united to the calx of tin, evidently remained floating in the water, not because the calx was too intimately combined with the acid solvent as in the first experiment, but because,
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for want of a sufficient attraction between them, it had been almost wholly decomposed as soon as they were put into water; and in boiling, it fixed itself with the bark colour upon the cloth but sparingly and slowly. This also happened in the second part of the operation; for which three pounds of cochineal, and six of this murio-nitric solution of tin, were at first employed; but the colour not rising sufficiently, another pound of cochineal, with four pounds more of the same solution, were added to the liquor in which the cloth was dyed for the space of two hours, when a considerable part of the colour still appeared floating, but not dissolved, in the water. So much, however, had been applied to the cloth, as to give it a passable scarlet colour, which however had penetrated but very little into its substance, and seemed, as Mr. Goodwin observed, to have been rather painted than dyed. It was, however, generally agreed, after a particular examination, that notwithstanding the great length of time in which the baize had been boiled with a very large proportion of the solution of tin, (*i. e.* 18 lb. for a single piece weighing but 90 lb.), its texture had not received the smallest injury; so that in this respect my last experiment proved less expensive than the first, though both together cost me near 30l.

As this murio-nitrate of tin, though exempt from the defects of the muriatic solution, had failed through others of a very opposite nature, I was induced to mix much greater proportions of nitric with the muriatic acid for dissolving tin, in order to see how much of the former could

could be used in this way, without so far yellowing the cochineal crimson as to preclude the use of any of the Quercitron yellow in the dying of scarlet, an effect which I still expected from the nitric acid, when used in a very large proportion; but to my great surprize, I could discover no such effect, even when I had dissolved the metal in nitric acid *alone*. At first I suspected some impurity in the acid which had been employed; but having procured a fresh supply, and ascertained its purity by the proper means, I still found that tin dissolved by it had not the least tendency to change the cochineal crimson towards a yellowish or scarlet hue; and that this effect, in the usual way of dying that colour, resulted wholly from the tartar, which is always employed at the same time. This fact I ascertained by repeated and varied experiments, in which I constantly found that cochineal, with the dyers' common solution of tin, and even with that made by nitric acid only, would produce nothing but a crimson without tartar; and that cochineal, with tartar, would produce a scarlet, not only with these last mentioned solutions, but also, *and equally well*, with the muriatic solution of that metal; and therefore, that every thing which had been taught and believed to the contrary was repugnant to truth. And here I cannot conceal my wonder, that an error of so much consequence, and so destitute of all foundation, should have been propagated and confirmed by so many acute reasoners and sagacious observers in other respects; for besides those eminent writers already mentioned, Mr. Pœrner has more recently adopted
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and propagated the same error, after making a great number of experiments, several of which, if they had been duly considered, would have taught him the truth on this subject*. This also was even more lately done by Mr. Berthollet, in his *Elemens de l'Art de la Teinture*, where, to adopt the words of Dr. Hamilton's Translation, he says, "Tartar, as we have seen, gives a *deeper and more rosy hue* to the colouring matter of cochineal, precipitated by the solution of tin. It moderates the action of the nitro-muriatic acid, which tends to give scarlet an orange cast, though this orange cast is not to be seen in the precipitate produced by the solution of tin, which is on the contrary of a fine red. It is probable that the solution of tin gives scarlet an orange tinge, by means of the action the nitro-muriatic acid exerts on the wool, which, as well as all other animal substances, it has the property of turning yellow."

"Thus (adds he), by putting more of tartar into the reddening, a deeper and fuller scarlet may be obtained; and on the contrary, the scarlet may be rendered more inclining to orange by omitting this ingredient." And he concludes the chapter by repeating this doctrine.

Here then it is manifest, that the nitro-muriate of tin and the tartar are each supposed to

* See *Instruction sur l'Art de la Teinture*, &c. a Paris 1791.

produce effects *directly contrary to those which are really produced* by them, the effects of each being ascribed to the other; a mistake capable of producing much disappointment and detriment.

Having made myself certain that the dyers' spirit or nitro-muriatic solution of tin, without tartar, would only dye a crimson with cochineal, I was induced to make an experiment therewith, instead of the muriate of tin, at the dye-house of the late Mr. Seward in Goswell-street, and with views similar to those which directed the experiments before made at Messrs. Goodwin. A piece of baize was accordingly boiled one hour and a quarter with the usual portion of nitro-muriatic solution of tin, (which had been prepared by Mr. Seward,) and with about $\frac{1}{4}$ of its weight of Quercitron bark, without any tartar. After which it was taken out dyed of a bright yellow, though paler than it would have been with the muriate of tin. The baize being rinsed, and the dying vessel emptied, and then filled a second time with clean water, about four-fifths of the cochineal usually employed for the like quantity of baize, and a farther suitable proportion of the solution of tin, were put into it, and the baize being dyed therein, as usual, took what was allowed to be a good scarlet. Mr. Seward, however, did not seem so fully convinced, as I had expected, of the advantage of compounding a scarlet in this way from the cochineal crimson and Quercitron yellow; and probably the experiment had not been attended with any very manifest success, or saving of cochineal, because the nitro-muriatic solution of
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tin, which had produced but a pale yellow with the Quercitron bark, had also acted more feebly in raising or exalting the cochineal colour than it usually does when assisted with tartar, which consists of a portion of vegetable alkali combined with an excess of its own peculiar acid; and therefore, whenever it is mixed with a solution of tin by any of the mineral acids, the tartar will be decomposed; because the mineral acids, by their superior attraction for, will unite with its alkaline basis, and disengage an additional portion of the tartarous acid, which will then unite with the metallic calx, previously abandoned by the mineral acid, and thus produce a *tartrite of tin*, which last, in the usual way of dying scarlet, inclines the cochineal crimson to a yellow hue, and at the same time, (as I have since found,) exalts its colour more than the nitro-muriatic solution of tin alone would be able to do; and it is only this production of a tartrite of tin that has obviated the ill effects which otherwise must have resulted from the sulphuric acid frequently contained in the common aqua-fortis used by the scarlet dyers. Not many years have elapsed indeed, since money was obtained from several eminent dyers in London, for a secret to *strengthen* their aqua-fortis, which they were to do by adding to it a portion of oil of vitriol; and though they were soon induced no longer to employ this secret, it may be concluded that they did not pay money for it without some previous trials, and at least an appearance of benefit from its use; and certainly a moderate portion of vitriolic acid would in this way operate a saving of the dearer nitric acid, since its action would be exerted only in decom-

decomposing the tartar, by uniting with its alkaline basis, and producing a sulphate of potash or vitriolated tartar, which seems no more hurtful to the scarlet dye than the nitrate of potash or salt-petre, which the nitric acid produces in the same way, where there is no vitriolic to take its place, in consequence of its superior attraction for the alkaline basis of tartar.

Though I had hitherto failed in my endeavours to compose a scarlet colour with advantage, so as to save that part of the cochineal which appeared to be misapplied, by being converted to the yellowish hue in the usual process, I had nevertheless full confidence in my former reasoning on this subject, and employed myself from time to time in searching after more suitable means for attaining this end. Some of my earliest experiments with a solution, or rather a calcination of tin by the sulphuric acid, had shewn me that this preparation was very unsuitable for my purpose, because it really exerted a destructive action on the cochineal colour, by reducing it from a crimson down to a kind of salmon colour, which indeed was the highest colour produced on cloth by dying it with cochineal and sulphate of tin; I therefore discarded the use of sulphuric acid for dissolving tin, until particular circumstances led me some time after to dissolve a portion of it by the muriatic acid, combined with about one-fourth of its weight of oil of vitriol; and by trying this solution, I found that it produced very good effects in dying, without any appearance of that corrosive property which had acted so mischievously in the experiments made with tin, dissolved

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by muriatic acid only. I was therefore encouraged to make and try other solutions of that metal by the same acids, united in various proportions; and have at length found reason to prefer a solution made by dissolving after the rate of about fourteen ounces of tin in a mixture of two pounds of oil of vitriol, (of the usual strength,) with about three pounds of muriatic acid. That which I have used was strong enough, with a sand-heat, to dissolve one-third of its weight of tin, and rather more than one-fourth of its weight of *zinc*, which last metal is most commodious for ascertaining the strength of muriatic acid, because it dissolves therein very rapidly in the common heat of the atmosphere. The muriatic acid should be first poured upon a large quantity of granulated tin, in a large glass receiver, and the oil of vitriol afterwards added slowly; and these acids mixed should be left to saturate themselves with tin, which they will do in time without any artificial heat; but the solution will be rapidly promoted by a sand heat.

This solution contained but little more than half as much tin as the muriatic solution which had been used in the first experiment made at the dye-house of Messrs. Goodwin and Co., yet the metallic part of it existed in a state so much more suitable for the purposes of dying, that a given quantity of it would produce much better effects than a like quantity of muriatic solution, containing nearly twice as much of the metal, and without any corrosive property, capable of doing the least mischief, unless used in much greater proportions than ever can be wanted for dying.

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The murio-sulphuric solution of tin, made in these proportions, will be perfectly transparent and colourless; and will probably remain so for many years, without becoming turbid, or suffering by any precipitation of the metal; at least none has appeared in some which I have kept for more than three years. It will produce full twice as much effect as the dyers' spirit, or nitro-muriatic solution of tin, with less than a third of the expence. It has moreover the property of raising the colours of, I believe, all adjective dyes, more than the dyers' spirit, and full as much as the tartrate of tin, without changing the natural crimson of cochineal towards the yellowish hue; and therefore, after having made a great number of experiments with it, I think myself warranted in strongly recommending this murio-sulphate of tin for dying the compound scarlet colour already described, (with the cochineal crimson and Quercitron yellow,) for which it will be found highly effectual and economical.

For this species of scarlet nothing is necessary but to put the cloth, suppose 100 lb. weight, into a proper tin vessel, nearly filled with water, in which about eight pounds of the murio-sulphuric solution of tin have been previously mixed, to make the liquor boil, turning the cloth as usual through it, by the winch, for a quarter of an hour; then turning the cloth out of the liquor, to put into it about four pounds of cochineal, and two pounds and a half of Quercitron bark in powder, and having mixed them well, to return the cloth again into the liquor,

making it boil, and continue the operation as usual until the colour be duly raised, and the dying liquor exhausted, which will be the case in about fifteen or twenty minutes; after which the cloth may be taken out and rinsed as usual. In this way the time, labour, and fuel, necessary for filling and heating the dying vessel a second time, will be saved; the operation finished much more speedily than in the common way; and there will be a saving of all the tartar, as well as of two-thirds of the cost of spirit, or nitro-muriatic solution of tin, which for dying 100lb. of wool, commonly amounts to 10s.; whereas, 8lb. of the murio-sulphuric solution will only cost about 3s. There will be moreover a saving of at least one-fourth of the cochineal usually employed, (which is generally computed at the rate of one ounce for every pound of cloth,) and the colour produced will certainly not prove inferior in any respect to that dyed with much more expence and trouble in the ordinary way. When a rose-colour is wanted, it may be readily and cheaply dyed in this way, only omitting the Quercitron bark, instead of the complex method now practised of first producing a scarlet, and then changing it to a rose by the volatile alkali contained in stale urine, set free or decomposed by pot-ash or by lime: and even if any one should still *unwisely* choose to continue the practice of dying scarlet without Quercitron bark, he need only employ the usual proportions of tartar and cochineal, with a suitable quantity of the murio-sulphate of tin, which, whilst it costs so much less, will be more effectual than the dyers' spirit.

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Several hundreds of experiments warrant my assertion, that at least a fourth part of the cochineal generally employed in dying scarlet, may be saved by obtaining so much yellow as is necessary to compose this colour from the Quercitron bark; and indeed nothing can be more self-evident, than that such an effect, *ceteris paribus*, ought necessarily to result from this combination of different colouring matters, suited to produce the compound colour in question. Let it be recollected that the cochineal crimson, though capable of being changed by tartar towards the yellow hue on one hand, is also capable by other means of being changed towards a blue on the other, and of thereby producing a purple without indigo or any other blue colouring matter: yet I am confident that nobody would believe a pound of cochineal so employed capable *alone* of dying as much cloth, of any particular shade of purple, as might be dyed with it, if the whole of its colouring matter were employed solely in furnishing the crimson part of the purple, whilst the other (blue) part thereof was obtained from indigo. To say that a pound of cochineal *alone* could produce as much effect or colour as a pound of cochineal and a pound of indigo *together*, would be an improbability much too *obvious* and *palpable* for human belief; and there certainly would be a similar improbability in alleging, that a pound of cochineal, employed in giving another compound colour (scarlet), could alone produce as much effect as a pound of cochineal and a pound of Quercitron bark, when the colour of this last was employed only in furnishing one of the component parts of the scarlet, for which a con-

siderable portion of the colouring matter of the cochineal must otherwise have been expended, which certainly happens in the new mode of dying scarlet, because the colour produced with an addition of the Quercitron yellow inclines no more towards a yellow, than the scarlet produced by yellowing a part of the cochineal colour in the usual method with tartar. I retain, therefore, at this moment, as much confidence as I ever had in the reality and importance of my proposed improvements in this respect*.

The scarlet composed of cochineal crimson and Quercitron yellow, is moreover attended with this advantage, that it may be dyed upon wool and woollen-yarn without any danger of its being changed to a rose or crimson, by the process of fulling, as always happens to scarlet dyed by the usual means. This last being in fact nothing but a crimson or rose colour, yellowed by some particular action or effect of the tartar, is liable to be made crimson again by the application of many chymical agents, (which readily overcome the changeable yellow produced by the tartar,) and particularly by calca-

* Of the benefit which I formerly expected to obtain by employing pot-ash to extract a part of the cochineal colour, which water alone did not appear capable of extracting, it must be remarked that I have sometime since convinced myself of its being an illusion; for, by repeated trials, I have found that the solid parts of powdered cochineal remaining after it has been boiled with the solution of tin, as in the common dying process, yield no colour worth notice, upon the application of pot-ash, the solution of tin enabling the water to extract the colour sufficiently; so that in truth there is no such waste of cochineal colour as I had supposed in the usual way of employing that drug.

reous earths, soap, alkaline salts, &c. But where the cochineal colouring matter is applied and fixed merely as a *crimson* or *rose* colour, and is rendered scarlet by superadding a very *permanent Quercitron yellow*, capable of resisting the strongest acids and alkalies, (which it does when dyed with solutions of tin,) no such change can take place, because the cochineal colour having never ceased to be crimson, cannot be rendered more so, and therefore cannot suffer by those impressions or applications which frequently change or spot scarlets dyed according to the present practice.

There is also a singular property attending the compound scarlet dyed with cochineal and Quercitron bark; which is, that if it be compared with another piece of scarlet dyed in the usual way, and both appear by day-light *exactly of the same shade*, the former, if they be afterwards compared by candle-light, will appear to be at least several shades higher and fuller than the latter; a circumstance of some importance, when it is considered how much this and other gay colours are generally worn and exhibited by candle-light during a considerable part of the year.

To illustrate more clearly the effects of the murio-sulphuric solution of tin with cochineal in dying, I shall state a very few of my numerous experiments therewith; observing, however, that they were all several times repeated, and always with similar effects.

1st, I boiled one hundred parts of woollen cloth in water, with eight parts of the murio-sulphuric solution of tin, during the space of ten or fifteen minutes; I then added to the same water four parts of cochineal, and two parts and a half of Quercitron bark in powder, and boiled the cloth fifteen or twenty minutes longer; at the end of which it had nearly imbibed all the colour of the dying liquor, and received a very good, even, and bright scarlet. Similar cloth dyed of that colour at the same time in the usual way, and with a fourth part more of cochineal, was found upon comparison to have somewhat less body than the former; the effect of the Quercitron bark in the first case having been more than equal to the additional portion of cochineal employed in the latter, and made yellow by the action of tartar,

2d, To see whether the tartrite of tin would, besides yellowing the cochineal crimson, contribute to raise and exalt its colour more than the murio-sulphate of that metal, I boiled one hundred parts of cloth with eight parts of the murio-sulphuric solution, and six parts of tartar, for the space of one hour; I then dyed the cloth, *unrinsed*, in clean water, with four parts of cochineal, and two parts and a half of Quercitron bark, which produced a bright aurora colour, because a double portion of yellow had been here produced, first by the Quercitron bark, and then by the action of tartar upon the cochineal colouring matter. To bring back this aurora to the scarlet colour, by taking away or changing the yellow produced by the tartar, I divided the
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the cloth whilst unrinced into three equal parts, and boiled one of them a few minutes in water slightly impregnated with pot-ash; another in water with a little ammoniac; and the third in water containing a very little powdered chalk, by which all the pieces became scarlet; but the two last appeared somewhat brighter than the first, the ammoniac and chalk having each rosed the cochineal colour rather more advantageously than the pot-ash. The best of these, however, by comparison, did not seem preferable to the compound scarlet dyed without tartar, as in the preceding experiment; consequently this did not seem to exalt the cochineal colour more than the murio-sulphate of tin; had it done so, the use of it in this way would have been easy without relinquishing the advantages of the Quercitron yellow.

3d, I boiled one hundred parts of woollen cloth with eight parts of the murio-sulphuric solution of tin, for about ten minutes, when I added four parts of cochineal in powder, which by ten or fifteen minutes more of boiling, produced a fine crimson. This I divided into two equal parts, one of which I yellowed or made scarlet by boiling it for fifteen minutes with a tenth of its weight of tartar in clean water; and the other, by boiling it with a fortieth of its weight of Quercitron bark, and the same weight of murio-sulphuric solution of tin; so that in this last case there was an addition of yellow colouring matter from the bark, whilst in the former no such addition took place, the yellow necessary for producing the scarlet having been wholly gained by a change and diminution of
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the cochineal crimson; and the two pieces being compared with each other, that which had been rendered scarlet by an addition of Quercitron yellow, was, as might have been expected, several shades fuller than the other.

4th, I dyed one hundred parts of woollen cloth scarlet, by boiling it first in water with eight parts of murio-sulphate of tin, and twelve parts of tartar, for ten minutes, and then adding five parts of cochineal, and continuing the boiling for fifteen minutes. This scarlet cloth I divided equally, and made one part crimson, by boiling it with a little ammoniac in clean water; after which I again rendered it scarlet, by boiling it in clean water, with a fortieth of its weight of Quercitron bark, and the same weight of murio-sulphate of tin; and this last, being compared with the other half, to which no Quercitron yellow had been applied, was found to possess much more colour, as might have been expected. A piece of the cloth, which had been dyed scarlet by cochineal and Quercitron bark, as in the first experiment, being at the same time boiled in the same water with ammoniac, did not become crimson, like that dyed scarlet, without the bark.

In this way of compounding a scarlet from cochineal and Quercitron bark, the dyer will at all times be able, with the utmost certainty, to produce every possible shade between the crimson and yellow colours, by only increasing or diminishing the proportion of bark. It has indeed been usual at times when scarlets, approaching nearly to the aurora colour, were in fashion,

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to superadd a fugitive yellow either from turmeric, or from what is called young fustic (*Rhus Cori-nus*); but this was only when the cochineal colour had been previously *yellowed as much as possible by the use of tartar*, as in the common way of dying scarlet; and therefore that practice ought not to be confounded with my improvement, which has for its object to preclude the loss of any part of the cochineal crimson, by its conversion towards a yellow colour, which may be so much more cheaply obtained than the Quercitron bark.

By sufficient trials, I have satisfied myself that the cochineal colours, dyed with the murio-sul-phuric solution of tin, are in every respect at least as durable as any which can be dyed with any other preparation of that metal; and they even seem to withstand the action of boiling soap suds somewhat longer, and therefore I cannot avoid earnestly recommending its use for dying rose and other cochineal colours, as well as for compounding a scarlet with the Quercitron bark.

I have thus freely given the results of a multitude of experiments, which have cost me some money, with not a little time and meditation; and I have given them without the least idea of ever claiming any kind of remuneration from the public; and though it may be some time before the truth and importance of what I here offer are fully recognized, I am confident this will happen sooner or later; and by putting it into every one's power to bring my ideas to the
test

test of experience, I shall have at least done my duty.

It remains, however, yet for me to communicate the effects of a considerable number of earthy and metallic bases upon the colouring matter of cochineal, which I shall state as briefly as possible, omitting all detail respecting proportions and modes of conducting the dying operations, which are to be understood as having been conformable to the common practice where nothing is mentioned to the contrary.

Woollen cloth, dyed with cochineal and nitrate of tin, produced a fine crimson, and this, boiled in the same liquor with tartar, was changed to a good scarlet. A similar, but rather better effect was produced by tin dissolved immediately in a mixture of aqua-fortis and tartar. The scarlet given by this tartaro-nitrate of tin appeared highly beautiful.

Tin put into aqua-fortis, with a considerable portion of refined sugar, afforded a very thick adhesive solution, which assumed a blackish brown colour, like that of *burnt sugar*, and being tried as a mordant in dying, it was found incapable of fixing the cochineal or any other colours. The tin in this state did not seem fitted to combine with the fibres of the cloth, and the sugar had manifestly suffered a kind of combustion. Spirit of wine, put with tin into aqua-fortis, also rendered the solution unfit to combine with wool, or serve as a mordant.

Tin,

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Tin, calcined with an equal quantity of salt-petre in a red-hot crucible, being thrown into water, afforded a milky solution, tasting very sensibly of the alkaline part of the salt-petre, and evidently suspending a considerable portion of the metallic calx. Cloth boiled in water with some of this solution, then rinsed, and dyed with cochineal, took a crimson, inclining to the purple; and this, boiled in the same liquor with tartar, was changed to scarlet.

I poured two pounds of aqua-fortis, with an equal weight of water, upon a large quantity of granulated tin, and leaving them together during the three summer months of 1790, I afterwards found near a pound of the calx of tin collected in lumps at the bottom of the glass vessel. This being separated and dried, some of it was finely powdered and *thoroughly washed*; then putting it with an equal weight of cochineal into water, I boiled cloth therein, which took a full equal crimson, somewhat deficient in brightness. Tartar being added to the liquor, and the cloth farther boiled therein, it became of a good scarlet. Lemon juice, used instead of tartar, produced the like effect. By substituting caustic volatile alkali for tartar and lemon juice, a crimson, greatly inclining to purple, was produced. The oxide of tin, therefore, does not act in all cases *merely as such*, but its effects often depend on triple, quadruple, and sometimes even more complex combinations, in which different saline and other parts of the compound remain permanently united, at least where the shades of colour depending on them are found permanent. It is thus that sea-salt, and other purely saline matters,

matters, which having no earthy or metallic basis, cannot become the basis of any adjective colour, produce *lasting* effects in modifying and varying the complexions of different colours.

It must, however, be observed, that though the calx of tin, after being thoroughly washed and dried, was capable of dying a crimson on woollens with cochineal, and a scarlet, where either tartar, lemon juice, or Quercitron bark were added, it would not permanently combine with or become the basis of these colours upon cotton; and indeed on woollen it was only the finer particles of the calx which really combined with the colouring matter and the wool, the grosser being always distinctly found at the bottom of the dying vessel; and when I attempted to impregnate woollen cloth with the oxide of tin separately, by boiling them together, I always found, on rinsing the cloth, and endeavouring to dye it with cochineal in a different vessel, that the oxide had not penetrated or united with the wool, so as to afford a basis for raising and fixing the colour, it being necessary for this purpose that both the oxide and the colouring matter should be mixed together in the dying vessel, and exert their mutual attractions for and upon each other, before they could be properly taken up by the cloth; and this was done better after they had been previously mixed and left together for several hours.

One ounce of the calx of tin before mentioned, unwashed, being dissolved in three ounces of muriatic acid, and woollen cloth being dyed

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with a tenth of its weight of this solution, and a twentieth of cochineal, it took but a very languid pale red colour. The calx of tin, which was immediately decomposed upon its intermixture with water, manifested very little disposition to penetrate or combine with the fibres of the wool; and after long boiling the greater part of it, and of the colouring matter, remained suspended in the dying liquor. Nearly similar effects resulted from a solution of tin by the oxygenated muriatic acid.

Cochineal with a solution of tin by muriatic acid, dyed a beautiful crimson; and with a solution of that metal, by a mixture of tartar and muriatic acid, a beautiful scarlet.

Cochineal with tin dissolved by muriatic acid and the acid of tar mixed, produced a dark crimson; and with tin, and a little manganese dissolved in muriatic acid, it produced a very bluish crimson.

Cochineal with tin dissolved by muriatic acid and borax mixed, dyed a very good crimson.

Cochineal with tin calcined by the long continued action of sulphuric acid, dyed a salmon colour; and with a recent solution of tin it produced a reddish salmon colour, inclining a little to the crimson. A like colour was produced with tin dissolved by equal parts of sulphuric and nitric acids mixed.

Oil of vitriol having been poured upon tartar and granulated tin, the mixture immediately became

came black, by the action of the sulphuric acid upon the carbonic basis, which, with hydrogen and oxygen, are the constituents of tartar. Cloth dyed with a tartaro-sulphuric solution of tin thus made, and cochineal, took an aurora colour.

Tin dissolved by the pure acid of tartar, separated from its alkaline basis, (by the means usually employed for that purpose,) dyed with cochineal on cloth a very beautiful scarlet, inclining a little to the aurora. A similar colour was produced by water saturated with cream of tartar, in which granulated tin had been kept six weeks.

Tin very readily dissolves by pure citric acid, and even by lemon juice; and the solution newly made, dyes with cochineal a most beautiful scarlet, inclining, like the preceding, a little to the aurora. Indeed, I have repeatedly found that the citric acid with tin, acts at least as efficaciously as that of tartar in yellowing the cochineal crimson. Nothing can exceed the beauty of scarlet dyed with the citrate of tin.

Granulated tin, dissolved by strong vinegar, acquired a very particular, and somewhat of an unpleasant smell; and with cochineal it dyed cloth of a scarlet, inclining a little to the crimson colour.

Tin dissolved by acid of tar produced with cochineal a colour between the scarlet and crimson shades.

Phos-

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Phosphoric acid produced a permanently transparent and colourless solution of tin; and this (phosphate of tin) with cochineal dyed an atropa colour.

Tin dissolved by fluoric acid, produced with cochineal a very good scarlet.

Such were the effects produced on woollen cloths by different preparations of tin, as bases for dying with cochineal. With other bases, cochineal gave the following colours to wool, viz.

With nitro-muriate of platina, a red; which, by the addition of chalk, became a chesnut colour.

With nitro-muriate of gold, a reddish brown.

With nitrate of silver, a dull red; and with muriate of silver, a lively reddish orange.

With the acetite of lead, a purple, inclining to the violet; and with nitrate of lead, a delicate lively colour, between the red and cinnamon, but inclining most to the former. A little murio-sulphate of tin, added to the liquor in which this last was dyed, soon changed it to a good crimson.

acetate

With either the sulphate, nitrate, muriate, or acetite of iron, cochineal produces a dark violet, and even a full black colour, when employed in sufficient quantity.

All the preparations of copper appear to sadden and debase the colouring matter of cochineal; and all those of mercury, which I have tried, do this in much greater degrees; most of

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them,

them, whilst they debase the colour, seem to annihilate a considerable part of it.

With nitrate of zinc, cochineal dyed a lively strong lilac colour; and,

With muriate of zinc, a colour like the preceding, but inclining a little more to the purple. Probably the iron usually contained in zinc may have contributed in these instances to incline the cochineal crimson so much to the blue or violet shades, since a purer oxide of zinc, the lapis caliminaris, being dissolved in muriatic acid, dyed (with cochineal) a scarlet but very little inferior to that commonly produced with the nitro-muriate of tin and tartar; and upon adding a little murio-tartrite of tin to the dying liquor, it soon produced a very beautiful scarlet. The pure oxide of zinc therefore seems to approach nearest to that of tin, in exalting the colouring matter of cochineal.

With different solutions of bismuth, cochineal produced various shades of lilac; some of them very lively and delicate; but all preparations of this semi-metal, instead of displaying and exalting the cochineal colour, tended to render a part of it latent. The oxide of bismuth, dissolved in strong vinegar, did this less than most of the other preparations; it dyed with cochineal a pretty good purple, and the murio-sulphate of bismuth, a salmon colour.

With nitrate of cobalt, cochineal dyed a good purple.

With nitrate of nickle, a dark lilac, inclining to the violet.

With

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With sulphate of manganese, an orange; and

With the nitrate of manganese, a colour resembling the madder red.

With crude antimony, dissolved by nitric acid, cochineal dyed a scarlet very much like that dyed with lapis calimmaris dissolved by muriatic acid, and very little inferior to the best scarlets given with the tin basis; and

With Macquer's arsenical neutral salt, or the acidulous arseniate of pot-ash, cochineal dyed a lively good purple.

Such were the effects of different metallic bases in dying with cochineal on woollens. It remains for me shortly to offer a few observations on the effects of the several kinds of earths, as bases for the cochineal colouring matter upon wool.

The use of sulphate of alumine, or common alum, for this purpose, is well known. The alumine, or earth of alum, (obtained by decomposing and precipitating it by pot-ash from water, saturated with alum,) when thoroughly washed, dried, and finely powdered, did not seem capable, in repeated trials, of fixing or serving as a basis of the cochineal colour on wool. In this respect it differed materially from the powdered calx of tin.

The same powdered alumine, however, being boiled up with cream of tartar, was so far dissolved by its acid, that with cochineal it dyed a good crimson, though not much better than
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what may be produced with the sulphate of alumine.

The same powdered earth of alum, dissolved by lemon juice, dyed with cochineal a very good rich full crimson.

The same powdered earth of alum, dissolved by nitric acid, (and forming nitrate of alumine,) produced a good red, inclining to the crimson.

The same dissolved in muriatic acid (muriate of alumine) dyed a crimson, differing but little from that produced with common alum.

Lime water, with cochineal, dyed a purple, which took but slowly, and required long boiling.

Sulphate of lime, or lime dissolved by sulphuric acid, dyed a full dark red.

Nitrate of lime, or lime dissolved by nitric acid, dyed a lively red, approaching to scarlet.

Muriate of lime, with cochineal, dyed a purple.

Cloth boiled in water with *nitrate of lime*, and then dyed in clean water with cochineal and tin, dissolved by aqua-fortis and tartar mixed, received a good scarlet.

Cloth boiled with chalk and alum, and then dyed in clean water with cochineal, took a good crimson, inclining to the bluish shade.

Sulphate

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Sulphate of barytes, or ponderous spar, not being soluble in water, could not be tried.

Muriate of barytes, or the earth of ponderous spar combined with muriatic acid, as a basis for the cochineal colour, dyed a good lively purple; and

Nitrate of barytes dyed a colour nearly similar, but inclining a little more to the crimson.

Magnesia alone did not combine sufficiently with the fibres of cloth, and with the colouring matter of cochineal, to serve as a basis for dying.

But magnesia dissolved by sulphuric acid, (forming Epsom salt,) dyed a lively purple with cochineal, though it took but slowly, and required long boiling; and acetite of magnesia dyed a lilac colour.

The siliceous earth, or powdered flints dissolved by a violent heat in a crucible with pure caustic alkali or pot-ash, was tried as a basis for the cochineal colour. At first the fibres of the cloth did not seem to have sufficient attraction for the siliceous basis and the colouring matter, to attach and fix them properly; but on adding a little sulphuric acid, so as to decompose and neutralize a part of the alkali, which had dissolved and was combined with the siliceous earth, the colour took freely, and rose to a *full rich pleasing purple*, in which the red or crimson predominated considerably; and this colour afterwards proved sufficiently durable.

It appears, therefore, that besides the metallic oxides and solutions, all the different kinds of earth, *i. e.* the aluminous, calcareous, and siliceous, together with those of magnesia, and of barytes or ponderous spar, are capable of fixing and serving as bases of the cochineal colouring matter; and we shall hereafter find, that they are capable of doing the same to other adjective colours; a fact never before ascertained, though of great importance, as well in respect of the practical improvements which it may produce, as of the general principles and conclusions to which it may lead us on this subject.

I have repeated nearly all the foregoing experiments with silk, instead of wool, and generally with effects less advantageous. Cochineal indeed, with the aluminous basis, dyes the crimson colour as well and as durably on silk as on wool, and the modes of producing a very lasting crimson by these means are well known. The oxides or solutions of tin, however, do not fix and reflect the cochineal colour on silk with the same degree of fullness and lustre as upon wool; probably because the former of these substances has less attraction than the latter, for the calx of tin and the colouring matter of cochineal combined together; and it has therefore been found impossible to dye a good lively scarlet on silk by the means which communicate that colour to wool.

The late Mons. Macquer indeed, about the year 1768, pretended to have discovered the means of dying a scarlet upon silk by a process
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which he published in the Memoirs of the Royal Academy of Sciences for that year. According to that process, he began by dying the silk first of a yellowish orange colour, with annotta applied in the usual way; then he soaked it for half an hour in a diluted solution of tin, made by a mixture of two parts of the nitric, with one of the muriatic acid; after which the silk was taken out, moderately pressed, and rinsed in clean water, though he afterwards found it better to omit the rinsing. To dye the silk, when thus impregnated with nitro-muriate of tin, he prepared a bath, by boiling from two to four ounces of cochineal, and a quarter of an ounce of cream of tartar, for each pound of silk, some minutes in water; after which he added cold water, until the heat of the liquor was reduced to what the hand could bear, and then put in the silk, and dyed it as usual, gradually raising the heat of the dying liquor, so as at last to make it boil for a single minute. I have several times repeated this process, but always found the colour produced by it very inferior to the scarlets usually dyed on woollen cloth; and Mr. Berthollet informs us, that this was also the case at the trials which Mr. Macquer himself made of his process at the dye-house of the Gobelines; and in truth there was nothing of any importance in Mr. Macquer's supposed discovery. It seems indeed to have been chiefly borrowed from a process published by Schele in 1751, excepting so far as relates to the colour first given with annotta, and excepting a difference in the proportion of muriatic acid for dissolving the tin; a difference, however, which did not render the solution in any respect more efficacious.

If the murio-sulphuric solution of tin, herein before described, be diluted with about five times its weight of water, and silk be soaked in it for the space of two hours, then taken out, moderately squeezed or pressed, afterwards partly dried, and then dyed as usual in a bath prepared with cochineal and Quercitron bark, in the proportion of four parts of the former to three of the latter, it will receive a colour approaching very much to a scarlet; and this may be made to receive more body by a farther slight immersion into the diluted murio-sulphate of tin, and a second dying in the bath from cochineal and Quercitron bark; and if afterwards a little of the red colouring matter of safflower be super-added by the usual mode of applying it, a good scarlet may be produced. By omitting the Quercitron bark, and dying the silk (prepared as before mentioned) with cochineal only, a very lively rose colour will be produced; and this may be yellowed so as nearly to approach the scarlet, by adding a large proportion of tartar to the cochineal in the dying vessel.

With lime water as a mordant, cochineal gave to silk a very agreeable purple; with muriate of barytes, a lively delicate lilac colour; with murio-sulphate of bismuth, a salmon colour; and with nitrate of cobalt, a very lively and beautiful purple; with nearly all the other metallic and earthy bases, cochineal produced similar but paler colours on silk than on wool.

Respecting cotton, my readers will recollect that I have already (at page 195) noticed the little attraction which this substance exerts upon the

the cochineal colouring matter, united with the solutions or oxides of tin. To illustrate this, Mons. du Fay caused a piece of cloth to be manufactured from a mixture of wool and of cotton, which having undergone the usual process for dying scarlet, became, as he describes it, "marbrée de couleur de feu & de blanc," (marbled with white and fire colours,) the cotton remaining perfectly white, though the wool was dyed scarlet; and he found a like want of attraction between cotton and the colouring matters of kermes, gum lacca, &c. He moreover found that a skain of white woollen yarn, and another of cotton, being at the same time, and in an equal degree, submitted to the action of the same preparation and dying liquors which are commonly employed for scarlet, the woollen yarn received the most beautiful scarlet, or, as he terms it, "*fire colour*," whilst the cotton remained as white as at first*. Similar effects have frequently occurred to me, and I have clearly perceived them to arise, not because the cotton is not capable of imbibing the scarlet dye, but because, having a weaker attraction for it than that which wool exerts on the particles of that dye, the latter *draws and exclusively appropriates to itself* all the colour contained in the dying liquor; though when cotton is subjected to the same process by itself, freed from the interference of a superior attraction from wool, it takes a scarlet colour, as I know by repeated trials, more slowly indeed, and paler, than that which is usually imbibed by woollen cloth. It is, perhaps, owing to this weaker attraction be-

* See Mem. de l'Acad. R^e des Sciences, &c. 1737.

tween the fibres of cotton and the scarlet dye, that the latter is so much less permanent on cotton than on wool; and it is also from this want of sufficient attraction, that the cochineal colour is found to take most beneficially on cotton, when the basis has been *first applied separately*.

Scheffer, in 1751, recommended the dying of scarlet on cotton in this way, by first soaking it in a diluted nitro-muriate of tin, and afterwards dying it with cochineal; but the colour being fugitive, little or no use was ever made of the process; though the late Dr. Berkenhout probably availed himself of it some years afterwards, when he pretended to have discovered the means of dying "scarlet, crimson, and "other colours, upon cotton and linen;" and though his process was not materially different from that of Scheffer, nor in any respect preferable to it, he found means to obtain 5000l. sterling from the British government, as a reward for making it public *. But as no use ever has

* Dr. Berkenhout's process having, I believe, never been published, I shall subjoin the account of it, which was "communicated by order of the Lords of the Treasury to "the Company of Dyers in the City of London, the 26th "of August 1779;" viz.

"Cotton or linen, either in yarn or piece, should be perfectly wet with hot water, and then wrung out, as is the common practice.

"This being done, it must be perfectly soaked in a solution of tin, diluted with an equal quantity of clear soft water.

"The cotton or linen being so far prepared, must be wrung out, but not forcibly; then it is to be nearly dried, laying

has been, or is likely to be made of this supposed discovery, I must hope, and indeed I

laying horizontally upon a hurdle, with a double linen sheet between, and covered with the same.

" The solution of tin being for scarlet, must be made of nitrous acid, and not of aqua-fortis; but for crimson, aqua-fortis must be used; and the bloom is to be given, after it comes out of the dye, by a small quantity of sal-ammoniac and pearl ashes dissolved perfectly in warm water; but this water must not be more than milk-warm.

" The colouring vat, for the scarlet or crimson, is simply cochineal in water, no hotter than the hand will bear; and as vegetable matter receives only the small particles of the colour from the nature of its pores; two ounces to a pound of the materials dyed may be necessary; but cotton or linen, fresh prepared, will draw from the same vat, heated as before, all the inferior shades from scarlet and crimson; and if any colour still remains in the vat, it may be taken out entirely by wool prepared in the usual manner.

" The same preparation of tin serves for the green and yellows, with the same materials only that are employed by dyers, except the best yellow, which is produced from turmeric *.

" It is necessary to observe, that after the preparation has been made use of for scarlet or crimson, the residue continues sufficiently strong for greens or yellows, even after it has been kept a considerable time.

" N. B. To make the best solution of tin with nitrous acid, it is necessary to have the strong smoaking spirit, to which an equal quantity of the purest river water must be added, and the proportions of the following ingredients are to the weight of spirit, $\frac{1}{18}$ of sal-ammoniac, $\frac{1}{2}$ refined nitre dissolved by little at a time; in this aqua-regia dissolve $\frac{1}{8}$ of granulated tin also by small quantities, to prevent too great an ebullition, which would weaken the solution considerably. The ingredients and proportions are the same, when a solution is to be made with aqua-fortis; but that spirit in general will not bear any water when a perfect solution is intended."

* Nothing can be more erroneous than this and several of Dr. Berkenhout's other observations.

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think it probable, that the Doctor had some better claim to a national remuneration, though from particular considerations it was not brought into public view.

Besides the fugitive nature of the scarlet dyed by Dr. Berkenhout's process, which indeed is calculated to produce only a crimson, and not a scarlet, unless some yellow colour be superadded by other means, (which he does not mention,) it is liable to injure the texture of the cotton or linen dyed with it, because the nitric calx of tin, applied as the basis, constantly absorbs oxygene from the atmosphere, and becomes corrosive, whereas, in the present case, this effect cannot be counteracted by occasional washings with soap.

Mr. Henry says, that "if a scarlet could be dyed without the use of nitrous acid, the tin basis might be employed for this purpose on cotton; but *that acid being requisite for the production of this beautiful colour*, and being highly corrosive to colours, this basis is prevented from being applied to that substance." — Here this ingenious chymist appears to have fallen into the universal error of believing, that nothing but a solution of tin by nitric, or nitrous acid, can dye a scarlet colour with cochineal.

If notwithstanding the want of sufficient permanency in the scarlet colour dyed with cochineal upon cotton, it should be deemed proper to apply it to that substance, the best way of doing this which I have yet found, is, to soak the cotton

ton (previously moistened) for about half an hour in a diluted murio-sulphuric solution of tin, as proposed for silk; then wring or press out the superfluous part of the solution of tin, and plunge the cotton into water, in which as much, or nearly as much, clean pot-ash has been dissolved, as will neutralize the acid still adhering to the cotton, so as thereby to decompose the oxide of tin, and cause it to be more copiously deposited or fixed in or upon the fibres of the cotton, which being afterwards rinsed in clean water, may be dyed with cochineal and Quercitron bark, in the proportions of about four pounds of the former to two and a half or three pounds of the latter. A full bright colour may be given to cotton in this way, which will bear a few slight washings with soap, and a considerable degree of exposure to air. Indeed the yellow part of the colour obtained from Quercitron bark will even bear long boiling with soap, as well as the application of strong acids without injury.

Cotton impregnated or printed with the aluminous mordant, as commonly applied by calico-printers for madder reds, will, if dyed with cochineal, receive a very beautiful crimson colour, capable of bearing several washings, and of resisting the weather for some time, though not long enough to deserve the appellation of a fast colour. I think, however, that it is advantageous for calico-printers, in dying madder reds upon the finer cottons or muslins, to add also a little cochineal, the crimson colour of which is admirably calculated to overcome the brownish yellow

yellow hue that degrades all madder reds, and arises from a portion of that particular colouring matter which produces the *fauve* or fawn colour herein-before mentioned, and which unfortunately always exists in madder. By this addition, the madder reds are rendered much more beautiful, so long as any part of the cochineal crimson remained, and afterwards they are no worse than if it had never been applied.

Cotton printed with iron liquor takes a very full black when dyed with cochineal, but I found this less durable than the same colour dyed from much cheaper matters. A great variety of other colours may be dyed upon cotton impregnated with different metallic or earthy bases; but as better colours may be more cheaply given by other means, I shall offer no farther explanations respecting them.

A strong decoction of cochineal, thickened with gum, and mixed with a suitable proportion of nitrate of alumine, being penciled upon cotton as a pro-substantive colour, afforded a very full beautiful crimson, which stood some washings, and a considerable degree of exposure to weather. Several of the different solutions of tin being employed, instead of the nitrate of alumine, produced very beautiful reds between the crimson and scarlet, and by a small proportion of Quercitron bark they were made scarlet. These colours indeed cannot be called fast colours, but they are much more lasting than some of the fugitive colours too often used by calico-

calico-printers, particularly the yellows from French berries.

Having at this time nothing more to offer respecting *animal* adjective colours, I shall next proceed to the *vegetable*, beginning with the yellow.

C H A P. XII.

Of the Properties and Uses of Quercitron Bark.

“ Il n’y a pas de propriété plus respectable que les découvertes de l’industrie.”

BERTHOLLET, *Ann. de Chymie*, tome vi.

THE *Quercitron* bark is produced by the *Quercus nigra* of Linnæus, which might now be more properly denominated *Quercus tinctoria*; and is one of the objects of a discovery, of which the use and application for dying, calico-printing, &c. are exclusively vested in me, for a term of years, by an act of parliament passed in the 25th year of his present Majesty’s reign.

The bark of this tree appears to consist of three parts or coats.

1st, The epidermis, or external coat, through which the several excretions of the tree are transmitted, which in part at least adhere to its outer surface, where they harden, and become almost

black, by condensation, and probably by an absorption of oxygene; and hence the Linnæan denomination has originated, that great naturalist having had no knowledge of the properties of this bark in dying.

2d, The middle or cellular coat, in which the colouring matter principally resides; and,

3d, The interior or cortical part, consisting chiefly of lamina, formed by the re-union of different vessels, which become more hard and fibrous, as they are placed nearest to the woody part of the tree, and have therefore less room to contain the colouring matter.

The epidermis, or exterior blackish coat, of this bark, affords a yellow colouring matter, which however is less pure, and more inclined to a brownish hue, than that of the other coats or parts; and it ought therefore to be separated by shaving. When this is done, and the remaining cellular and cortical parts are ground by mill-stones, they will separate partly into a light fine powder, and partly into stringy filaments or fibres, which last yield but about half as much colour as the powder, and therefore care should be always taken to employ both together, and as nearly as possible in their natural proportions, otherwise the quantity of colour produced may either greatly exceed or fall short of what is expected. The Quercitron bark thus prepared and proportioned will generally yield as much colour as eight or ten times its weight of the weld plant, (*Reseda luteola*, Lin.) and as much as about four times its weight of the chipped

chipped old fustic (*Morus tinctoria*, Lin.): but the colouring matter of the bark in its nature and properties most nearly resembles that of the weld plant; with this advantage however, that it is capable *alone* of producing more cheaply all or very nearly all the effects of every other yellow dying drug; and, moreover, some effects which are not attainable by any other means yet known.

The Quercitron colouring matter may be readily extracted by water, even when it is only blood warm; but if the infusion be strained and left at rest, a small portion of resinous matter will separate and subside in the form of a whitish powder, capable of giving colours similar to those of the non-subsiding parts or particles. The clear infusion being evaporated, will afford an extract which, when completely dried, has, I think, commonly weighed as much as about one twelfth of the bark from which it was obtained, and yields nearly as much colour as the whole of the bark. But it has been found very difficult to make this extract in any large quantity, so as to render it capable of giving colours equal or nearly equal in beauty to those obtained *directly* from the bark itself; because if the evaporation be rapidly performed, with a considerable degree of heat, the colour always becomes tarnished, probably by a combination of Oxygene, producing effects similar to those of a slight combustion; and if the evaporation be conducted *slowly*, the colouring matter suffers greatly by another change like that to which the decoction of weld is always liable, and by which it usually spoils by keeping, even in less than 24 hours.

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There are several varieties of the *Quercus nigra*, all containing a portion at least of the same species of colouring matter; but some of them, (particularly the *Quercus nigra digitata*, and the *Quercus nigra trifida*, both of Marshall,) which, besides the yellow, contain a species of the *fauve* or fawn colour, which tarnishes the yellow, and in calico-printing occasions another bad effect, that of staining those parts of the cotton or linen intended to be kept white, so as to make the bleaching of them afterwards very difficult. The barks of these last mentioned varieties have frequently been mixed with that of the better sort, and sometimes in considerable quantities, (through the ignorance or the inattention of labourers employed in the collection,) so as to bring discredit upon this new and truly valuable dying drug: but there is reason to hope, that such improper mixtures will hereafter be avoided, in consequence of the very particular instructions which have been given for that purpose.

The decoction of Quercitron bark appears to be of a yellowish brown colour, which is darkened by alkalies, and rendered lighter by acids; alum dissolved in it, separates but a small portion of the colouring matter, which subsides in the form of a deep yellow precipitate. Either the muriate, the nitro-muriate, or the murio-sulphate of tin, mixed with a decoction of the bark, produces an exceedingly beautiful lively yellow, and occasions a much more copious precipitation than the allum; probably because the calx of tin unites with the colouring matter in a much larger proportion.

Sulphate of iron dissolved by a decoction of this bark, produces a copious dark olive precipitate, and the clear supernatant liquor remains of a light olive green.

Sulphate of copper in the like decoction, occasions a precipitation which is of a yellow inclining to the olive, and leaves the supernatant liquor of a yellowish green.

The effects of other bases and chymical agents upon the colouring matter of the bark, so far as they appear of any importance, will be discoverable from the following account of its various uses in dying and calico-printing.

Of the Application of Quercitron Bark for the Dying of Wool and Woollen Cloths with an Aluminous Basis.

WOOL, and the cloths or stuffs made from it, ought, in all cases, to be scoured before they are dyed, in order to separate a kind of grease with which the fibres are naturally covered. This is usually done by immersing the wool or cloth for about a quarter of an hour in stale urine, diluted with three times as much water, and kept nearly of a scalding heat; it is afterwards to be thoroughly rinsed in clean water, and then dyed without any previous drying, that the colour may apply itself more equally.

Alumine, or the earth of alum, precipitated by clean potash, and repeatedly washed in pure water, being boiled with Quercitron bark, readily

dily united with its colouring matter, and produced a yellow inclining very much to the golden or, as it is called, the *yellow* hue; and wool boiled in this mixture for the space of half an hour, took a brownish yellow, which, however, seemed to have been but superficially applied, the earth of alum in its undissolved state, not being able sufficiently to enter the pores of the wool even when they are distended by boiling water.

The earth of alum dissolved by the vegetable, the fossil, and the volatile alkalies separately, as well in their mild as in their caustic states, was found to dye yellow colours of different shades, with the Quercitron bark upon wool; but they were all inferior to those given by the same basis (alumine) when dissolved by acids.

The cheapest and most simple method of applying the Quercitron colour upon wool, is that of boiling up the bark with its weight or a third more than its weight of sulphate of alumine (common alum) in a suitable portion of water for about ten minutes, and then dyeing therein the wool or cloth previously scoured as before mentioned, taking care to give the higher colours first, and the paler straw colours afterwards. In this way yellows not wanted to be very full or bright may be dyed very expeditiously and cheaply; and they may afterwards be considerably raised and enlivened, by passing the wool or cloth unrinsed a few times through hot water, into which a little clean powdered chalk has been previously stirred, in the proportion of about a pound or a pound and a half of chalk for each 100lb. weight of wool or cloth. The bark, when used in dyeing, (being
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first ground,) should always be tied up in a linen bag of a loose open texture, and suspended in the dying liquor by a cord, with which it may be dragged occasionally backwards and forwards through it, to extract and spread the colouring matter more equally.

But when the bark and alum are boiled together and united in this way, the colour does not afterwards fix itself either so readily, or so copiously upon the wool or cloth, as when the aluminous basis has been first applied separately in the common mode of preparation; and therefore this simple and cheap method of applying the Quercitron colour is only suited for straws and pale yellows, especially as there is reason to suspect, that the adjective colours of every kind are not so durable when dyed with an aluminous basis in this way, as when they are dyed upon a like basis previously conveyed into and fixed in the substance which is to be dyed.

As often, therefore, as any thing more than a pale yellow is intended to be given from the Quercitron bark and the aluminous basis upon wool or cloth, the latter should be boiled in the common way, but *without either tartar or argol*, for the space of an hour or an hour and a quarter, with about one sixth or one eighth of its weight of alum, dissolved in a suitable quantity of water, and then *without being rinsed* it should be put into a dying vessel, with clean hot water, and about as many pounds of powdered bark, (tied up in a bag,) as there were used of alum to prepare the wool or cloth, which is then to be turned as usual by the winch through the boiling liquor

liquor, until the colour appears to have taken sufficiently; and then about one pound of clean powdered chalk for every 100lb. of the wool or cloth, may be mixed with the dying liquor, and the operation continued eight or ten minutes longer, when the yellow will have become both higher and brighter by this addition of chalk.

The yellows given in this way from the Quercitron bark, are infinitely better and considerably cheaper than any which can be given from old fustic with an aluminous basis: indeed they approach nearly to those given by weld with the common preparation of alum and tartar, and are in every respect as durable; though it must be confessed, that they have less of that lively greenish or lemon hue, for which the weld yellows are particularly valued: this, however, may be readily and cheaply obtained in the *utmost perfection* from Quercitron bark, by means which will hereafter be explained.

Wool or cloth which has been first properly dyed blue in the common indigo vat, may be made to receive any of the various shades of green which are usually given in this way from weld, by boiling the blue wool or cloth, (after it has been well rinsed,) in water with about one eighth of its weight of alum, as just directed for producing a yellow, and afterwards dying it unrinsed with about the same quantity of bark, and a little chalk, which should be added towards the end of the process, as already described. Greens of less body may be dyed with smaller portions of bark and alum.

In the same way, cloth which has previously received the proper shade of Saxon blue, may be dyed of a beautiful Saxon green: it will be proper, however, for this purpose, that the blue cloth should be first very well rinsed to separate, as far as water will do it, the acid which may have been imbibed from the sulphate of indigo, and which has a strong tendency to throw down and weaken the Quercitron as well as the weld yellows. But as mere rinsing in water will separate only a small part of this acid from the cloth, (with which it combines in a certain degree,) it will be proper to add about three pounds of chalk, with ten or twelve pounds of alum, for the preparation liquor of 100lb. weight of cloth, which is to be turned and boiled as usual for about an hour; and then, without changing the liquor, ten or twelve pounds of bark powdered and tied up in a bag, may be put into it, and the dying continued, taking care frequently to agitate the bag, in order that the colour of the bark may spread equally through the liquor. It will be found, however, that the yellow will manifest itself but slowly in this way by reason of the sulphuric acid imbibed with the blue colour, joined to that of the alum in the preparation liquor, which the portion of chalk before mentioned will not have been sufficient to overcome; and, therefore, when the dying with bark has continued about fifteen minutes, it will be proper to add another pound of clean powdered chalk, stirring it well through the liquor, and to repeat this addition afterwards once, twice, and even three times at intervals of six or eight minutes, if the colour does not rise sufficiently without it. By these additions, the Quercitron

yellow will manifest and apply itself abundantly and equally, so as to produce very beautiful greens, which, by varying the proportions of indigo as well as of bark and alum, may be varied at pleasure. The chalk, in this case, does not merely answer the purpose of decomposing the acid left in the cloth by the sulphate of indigo and the alum, but by uniting with this acid, it becomes a sulphate of lime, and fixes itself, in part at least, as a basis in the fibres of the cloth, where it helps to raise the colour, and also to render it a little more durable. At present the Saxon greens are commonly dyed with the old fustic; because the colour of this wood is not thrown down by acids so much as that of the bark and weld: and this difference enables the dyer, when he has extracted the fustic colour by previous boiling, to mix the sulphate of indigo therewith, and dye the cloth green by one operation after it has been prepared as usual with alum and tartar. The process, however, which I have mentioned for doing this with bark, is full as cheap and as expeditious, and the green produced will be more beautiful, because the Quercitron yellow is much more bright and clear than that of fustic.

At pages 210, 211, 212, and 213, I have described a method of combining the Prussian blue and the Quercitron yellow upon an aluminous basis, so as to produce a green colour, which I had flattered myself might be advantageously employed upon wool: further trials, however, have manifested so much difficulty in applying the colour equally, that I have now but little expectation of its being successfully employed in this

this way, and shall therefore say no more of it at present.

Durable yellows may also be dyed upon wool, with either the muriate, the nitrate, or the acetate of alumine, but not with any superiority of colour which could compensate for the increased expence of these aluminous preparations.

Of the best Methods of dying upon Wool and Woollen Cloths with Quercitron Bark and the Tin Basis.

In the preceding chapter I have mentioned the different effects of some of the preparations of tin in exalting the colour of the Quercitron Bark, as well as that of cochineal; and it will be remembered, that *for this purpose*, I found the muriate and the murio sulphate of tin, preferable to any other of the preparations of that metal; I observed, however, that the former of these had an injurious action upon the fibres of wool and cloth, unless when sparingly and carefully employed, and was therefore less proper for general use than the solution of tin, made by a mixture of muriatic and sulphuric acids, as described at page 290 of this volume; to which my readers will be now pleased to recur.

In order to dye 100lb. weight of cloth or woollen stuffs of the highest and most beautiful orange yellow, only 10lb. weight of Quercitron bark, and the same weight of murio sulphate of tin, will be required; the bark powdered and tied up in a bag, may be first put into the dying vessel with hot water, for the space of six or eight minutes,

minutes, then the murio sulphate of tin may be added, and the mixture well stirred for two or three minutes; after which the cloth, previously scoured and thoroughly wetted, may be put into the dying liquor and turned briskly for a few minutes: the colour applies itself in this way, so equally to the cloth, and at the same time so quickly, that after the liquor begins to boil, the highest yellow may be produced in less than 15 minutes, without any danger of its proving uneven. High shades of yellow, somewhat approaching to those dyed from bark in the way just mentioned, are frequently given with the rhus cotinus, (commonly, though improperly called young fustic,) and the dyers' spirit, or nitro muriate of tin; but the colour so given, is much less beautiful and more fugitive, as well as more expensive, than that obtained from the bark as just described.

When a very bright golden yellow, approaching less to the orange, is wanted, seven or eight pounds of murio sulphate of tin, with about five pounds of alum, and ten pounds of bark will suffice for 100lb. of cloth; the bark being first boiled a few minutes, then the murio sulphate of tin, with the alum, added, and the cloth afterwards dyed as just directed. Pure bright yellows of less body, may be produced by employing smaller portions of bark, murio sulphate of tin and alum, in the same way: and, indeed, all the possible shades of *pure bright yellow*, may be given with the utmost ease and certainty, by only varying the proportions of these ingredients. But where it is expedient to give that *lively, delicate greenish tinge* which, for certain purposes is so much

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much admired, and which the weld alone has been supposed capable of giving; white argol, or tartar, must be also employed with the bark, murio sulphate of tin and alum, in different proportions, according to the particular shade intended to be given. Thus, e. g. for a full bright yellow, delicately inclining to the greenish tinge, it will be proper to employ about eight pounds of bark, and six pounds of murio sulphate of tin, with six pounds of alum, and four of clean white tartar or cream of tartar; a little more alum and tartar will render the yellow more delicate, and give it more of the greenish tinge; and where this clean, lively, delicate greenish tinge is wanted in the greatest possible perfection, it will be proper to use the bark, murio sulphate of tin, alum and tartar all together in equal quantities. These last delicately greenish lemon yellows, are but very seldom if ever wanted to be dyed of much fullness or body, and therefore ten pounds of bark, and the like quantities of murio sulphate of tin, alum, and tartar, will generally prove sufficient to dye three or four hundred pounds weight of cloth or woollen stuffs of the colours in question; for which purpose the bark is to be first boiled a few minutes in water only, then the other ingredients are to be added, and mixed in the liquor by stirring and a few minutes boiling, and afterwards the cloth put into the liquor (first cooled a little) and turned briskly through it until the colour appears sufficiently raised. The pieces intended for the highest shades should be always dyed first, and those for weaker shades afterwards. When about two thirds of the whole quantity of cloth has been dyed, it will generally be found, that the liquor, by continuing to extract

tract colouring particles from the bark, has acquired an over proportion of the latter, and wants a small addition of murio sulphate of tin, alum, and tartar, (perhaps a pound of each,) to enable it to give the same delicately pale, though lively greenish tinge as at first: and indeed a surer way of giving these very pale greenish shades with exquisite delicacy and beauty, is to boil the bark with a small proportion of water in a separate tin vessel for the space of six or eight minutes, then add the murio sulphate of tin, alum, and tartar, and boil them all together for about fifteen minutes, and afterwards put a little of this yellow liquor into a dying vessel, previously supplied with water sufficiently heated, and the mixture being properly stirred, to begin dying the cloth as usual, adding farther supplies of the yellow liquor from the first vessel, by a little at a time, as fast as it may be wanted. In this way the palest and most delicate shades may always be dyed with ease and certainty; and those who have never seen the effects of this process, will hardly conceive the exquisite beauty and delicacy of these pale, but lively greenish lemon yellows, which certainly cost less than any similar colours given, if such can be given, by any other means. Weld is unquestionably the only dying ware capable of producing effects similar to those of the bark in this respect, and at the average price it will prove nearly four times as costly, regard being had to the smaller portion of colour which it affords, besides the expence of long boiling, which the bark does not want, to extract its colour. Indeed it may generally be computed, that the yellows dyed from Quercitron bark, with murio sulphate of tin and alum, do not cost in
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dying materials, more than one penny for each pound of cloth, and that in time, labour, and fuel, they do not cost half as much as those usually given by other means. And this is also true of the more delicate shades given by bark, murio sulphate of tin, alum, and *tartar*; for though this last ingredient be expensive, it is wanted only for the paler colours, which require smaller portions of dying materials, and therefore do not cost more than the highest shades given without it.

A greenish tinge may, indeed, be produced without tartar, by employing in its stead a little verdigrise dissolved by vinegar along with the bark, &c. but I think it is neither so lasting, nor so delicately clean and beautiful as that produced by the use of tartar. The sulphate of indigo will also produce this greenish tinge if employed in a very small quantity with the bark, murio sulphate of tin, and alum; but it has a tendency to fix itself so quickly upon the fibres of wool or cloth, that great care is necessary to hinder it from taking unequally, and the tinge produced by it is, moreover, somewhat liable to cast or fly, as the dyers say, in the finishing part; whilst the greenish tinge resulting from the use of tartar as before directed, will leave the press perfectly clear and bright. Indeed the colours obtained from Quercitron bark by these means, are very durable; they withstand even the action of strong mineral acids and of boiling soap suds, as well as exposure to air. This last, indeed, they are principally enabled to resist by the good effects of alum, and more especially of tartar. Since the highest yellows, which approach very nearly to
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the orange, and which are best dyed either with muriate, or murio sulphate of tin and bark, though they bear the action of soap and of acids in a wonderful degree, are liable after some time to loose a considerable part of their lustre, and acquire a brownish complexion by exposure to the sun and air. This is also true of yellows dyed with nitro muriate of tin (dyer's spirit) as a mordant, not only when employed with the bark, but with weld, and in a greater degree with fustic and other yellow vegetable colouring matters. In some of which this defect is not so well obviated by alum and tartar, as it is in the Quercitron and weld yellows.

I must here remark, that tin, by whatever means dissolved, when applied as a basis for dyeing wool, renders the fibres a little harsh; so that they neither run so far nor so easily in spinning as they would otherwise do, and the wool itself is apt to appear coarser; which is one reason for not dyeing scarlet in the fleece, and it may be one for not dyeing wool yellow with any of the solutions of tin as mordants, until it has been woven, or at least spun; though I am persuaded this defect is in a great degree obviated by employing the murio sulphate of tin, with a mixture of alum, or of alum and tartar, and combining these with the colouring particles of the bark, (in the ways which I have described,) *before* they are applied to the wool or cloth.

When yellows not quite so lively and beautiful can be made to answer, a much smaller proportion of the sulphate of tin will prove sufficient; five pounds thereof, for instance, may be boiled
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with ten pounds of bark, ten pounds of alum, and two or three of tartar, and the cloth dyed as before directed. The decomposition and re-composition which result from a mixture of tartar with murio sulphate of tin, will be readily conceived from what has been mentioned on this subject in the preceding chapter.

By using very small proportions of cochineal with the bark, murio sulphate of tin, &c. the colour may be raised to a beautiful orange, and even to an aurora. Madder also employed in this way, raises the Quercitron yellow, but the effect is less beautiful than with cochineal; and this is also the case when madder is employed with weld.

At pages 189 and 190, I have made some mention of the means of dying woollen cloth topically or partially, and since that time I have found, that by mixing a strong decoction of the bark, with a suitable proportion of murio sulphate of tin, &c. and thickening the mixture, as for the prosubstantive topical yellows hereafter to be described for calico-printing, then applying the mixture by a pencil to the woollen cloth, covering the pencilled parts with paper, so as to prevent the moist colour from spotting the other parts, afterwards folding up the cloth and tying it in a bag made of that kind of oiled linen which is used for bathing caps, so as to exclude water, and then keeping it immersed in boiling water for a quarter of an hour, a full and beautiful yellow was fixed upon the parts which had been pencilled, without any farther running or spreading of the colour. The same mixture pencilled upon cloth
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which had been previously dyed Saxon blue, produced a beautiful green where it had been pencilled. Diluted sulphate of indigo pencilled upon scarlet cloth and treated in the same way, produced a full black; and it seems to be easy, by employing proper mixtures in this way, to produce all the varieties of colours topically upon woollen stuffs: as far as I can judge, the oiled linen, which I believe was never before employed for this purpose, is much more suitable to it than the means now in use.

The most beautiful Saxon greens may be produced very cheaply and expeditiously by combining the lively yellow which results from Quercitron bark, murio sulphate of tin, and alum, with the blue afforded by indigo when dissolved in sulphuric acid, as for dying the Saxon blue.

To produce this combination most advantageously, the dyer, for a full bodied green, should put into the dying vessel after the rate of six or eight pounds of powdered bark (in a bag) for every 100lb. weight of cloth, with only a small proportion of water as soon as it begins to grow warm; and when it begins to boil, he should add about six pounds of murio sulphate of tin, (with the usual precautions,) and a few minutes after, about four pounds of alum; these having boiled together five or six minutes, cold water should be added, and the fire diminished so as to bring the heat of the liquor nearly down to what the hand is able to bear; and immediately after this, as much sulphate of indigo is to be added as will suffice to produce the shade of green intended to be dyed, taking care to mix it thoroughly with
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by stirring, &c.; and this being done, the cloth previously scoured and moistened, should be expeditiously put into the liquor, and turned very briskly through it for a quarter of an hour, in order that the colour may apply itself equally to every part, which it will certainly do in this way with proper care. By these means, very full, even, and beautiful greens may generally be dyed in half an hour; and during this space, it is best to keep the liquor at rather less than a boiling heat. Murio-sulphate of tin, is infinitely preferable, for this use, to the dyer's spirit; because the latter consists chiefly of nitric acid, which by its highly injurious action upon indigo, would render that part of the green colour very fugitive, as I have found by repeated trials. But no such effect can result from the murio-sulphate of tin; since the muriatic acid has no action upon indigo, and the sulphuric is that very acid which alone is proper to dissolve it for this use.

Respecting the beauty of the colour thus produced, those who are acquainted with the unequalled lustre and brightness of the Quercitron yellows, dyed with the tin basis, must necessarily conclude, that the greens composed therewith will prove infinitely superior to any which can result from the dull muddy yellow of old fustic: and in point of expence, it is certain that the bark, murio-sulphate of tin, and alum, necessary to dye a given quantity of cloth in this way, will cost less than the much greater quantity (six or eight times more) of fustic, with the alum necessary for dying it in the common way; the sulphate of indigo being the same in both

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cases. But in dying with the bark, the vessel is only to be filled and heated once; and the cloth, without any previous preparation, may be completely dyed in half an hour; whilst in the common way of producing Saxon greens, the copper is to be twice filled; and to this must be joined the fuel and labour of an hour and an half's boiling and turning the cloth, in the course of preparation, besides nearly as much boiling in another vessel to extract the colour of the fustic, and after all, the dying process remains to be performed; which will be equal in time and trouble to the whole of the process for producing a Saxon green with the bark; so that this colour obtained from bark will not only prove superior in beauty, but in cheapness, to that dyed as usual with old fustic.

Mr. Dambournay, in the supplement to his "Recueil de procedés & experiences sur les teintures solides," &c. mentions various experiments made by him with the Quercitron bark, from which he concludes, that in order to produce the good effects which I had previously described as resulting from its use in dying woollen cloths, these should be first impregnated with a tin basis, and then dyed in the manner which I had directed. In this way, says he, I obtained full shades of that beautiful yellow, a little greenish, but very durable, ("de cé beau jaune un peu verdâtre & tres solide,") which is so well suited to produce a *fine green*, either by the indigo vat, or by the composition for Saxon blue, i. e. sulphate of indigo. And having applied this latter by the common mode of dying, to cloth which had previously received the

the Quercitron yellow, and also to cloth dyed yellow with the Lombardy poplar, (which in other respects he greatly commends,) he found that the former which had received the bark yellow, took a fine dragon green, ("un beau vert dragon,") and the latter nothing better than a greenish olive. It is true that Mr. Dambournay computes the expence of dying with the Quercitron bark as greatly surpassing that of dying with the Lombardy poplar. But his computation was founded on very erroneous suppositions, joined to the circumstance of his calculating the muriatic acid to cost near two shillings and sixpence sterling the pound weight, which is more than six times its real cost; tho' this may probably have been nearly the price which it bore in France, whilst the *Gabelle* subsisted there.

The nitro muriate of tin, (dyer's spirit,) tho' it produces good yellows with Quercitron bark, produces them in a much weaker degree than the murio sulphate of that metal; which is really the cheapest, and most efficacious, of all the solutions or preparations of tin, for dying the Quercitron as well as the cochineal colours.

The sulphuric acid by itself dissolves, or rather calcines, a large portion of tin, if allowed to act upon it for any considerable time; and this solution joined to the bark, with alum and tartar, produces bright strong yellows on cloth, though I think they appear less soft and beautiful, than those dyed either with the muriate, or murio sulphate of tin. This metal dissolved, or rather calcined, by a mixture of the nitric and sulphu-

ric acids, is still less suitable for dying with the bark.

Tin dissolved by muriatic acid, to which one third of its weight of clean white tartar had been previously added, produced a very bright and delicate yellow with the bark, upon cloth, and this, by longer boiling, was raised to a full and beautiful orange. Tin dissolved in strong nitric acid, (double aqua fortis,) with an addition of one third of its weight of tartar, also produced a very good yellow, though somewhat inferior to the last.

Upon putting tartar, with a portion of tin, into a glass vessel with strong colourless sulphuric acid, the latter, or rather its oxygenous part, by combining with the inflammable part of the tartar, immediately rendered the mixture as black as ink; and the solution of tin produced by it, was found of but very little use as a mordant for dying with the bark.

A solution of tin, by the oxygenated muriatic acid, whilst secluded from light, retains its oxygenous part, and with it the power of weakening a great number of adjective colours; a power which depends neither upon the oxygene, nor the muriatic acid separately, but upon the new properties which they acquire by combination. The oxyd of tin, produced by the action of the nitric acid upon that metal, contains a large portion of oxygene; and yet it raises, instead of weakening the Quercitron yellow: but when this oxyd is dissolved in muriatic acid, it produces only a very feeble lifeless yellow

yellow with bark; though tin not previously oxygenated will, when dissolved by the same (muriatic) acid, act most powerfully in exalting the Quercitron yellow: which proves, that this defect of colour does not result from the presence of oxygen alone, but from its combination with muriatic acid. The defect in this case is exactly similar to that which occurs when tin, dissolved by oxygenated muriatic acid, is employed with the bark; and in both cases, the very feeble yellows produced, resemble that which I have described in the last chapter, as resulting from the use of tin, dissolved by muriatic acid, oxygenated by the addition of about one third of its weight of nitric acid: a similar effect was also produced by employing tin calcined by sulphuric acid, and then dissolved in the muriatic, as a mordant with the bark.

Cloth boiled in water with the muriate of tin and tartar, has sometimes been made yellow, and sometimes of a chesnut brown, *only* from the action of this mordant, unassisted by any colouring drug. These discolorations seem to depend upon the particular state of the cloth, as being more or less freed, either from the natural swint of the wool, or the grease commonly applied to it for particular purposes. Discolorations of this kind are not easily removed; they withstand the action of sun and air for a considerable time, and if cloth so discoloured be dyed with either bark, or with cochineal, the colour will appear tarnished; for which reason the application of muriate of tin, with tartar *only*, as a mordant, ought to be avoided, unless the dyer be very certain

certain that the cloth has previously been perfectly well scoured.

A few lumps of the dry oxyd of tin mentioned at page 118, having been finely powdered and mixed with a suitable quantity of decoction of Quercitron bark, the mixture was found capable of dying a very full and bright yellow upon woollen cloth. The colour however being exposed to the action of sun and air, very soon acquired a brownish complexion. Some of the same oxyd of tin reduced to powder, having been washed in warm water, to remove the adhering acid, as far as water could remove it, was found to be still capable of combining with the colouring matter of the bark, so as to dye cloth yellow; especially when the oxyd had been previously suffered to remain mixed with the decoction of bark, for some hours, in a warm situation. Cotton also took a yellow colour by dying in this mixture; but it was easily removed by washing with soap, and therefore was I think only applied superficially.

I have but little to offer respecting the use of copper, or rather of the oxyd and solutions of that metal *alone*, as mordants or bases for dying with Quercitron bark on wool or cloth. Their general effect is to raise and fix the Quercitron yellow; but at the same time to give it a greenish or rather an olive complexion. Wool dyed with a tenth of its weight of bark, and half as much sulphate of copper, received an agreeable colour, between the yellow and the olive. The bark, with muriate of copper, seemed to impart but little colour to wool for some time; but a little

little chalk being added, a full yellowish olive was produced. This also proved to be the case, when nitrate of copper was employed with the bark, until chalk had been added; and then the wool speedily imbibed a yellow, delicately inclining to the olive hue. Verdigrise with the bark produced a yellowish olive on wool; which, by the addition of chalk, was brightened, and made to approach nearer to the yellow. These colours appeared to be sufficiently lasting.

Drab colours of various shades may be most expeditiously and cheaply dyed by the Quercitron bark, and an iron basis. For this purpose the bark may be boiled a few minutes in a copper vessel, with one half, one third, or one fourth of its weight of sulphate of iron, (copperas,) according to the shade required, and the liquor having been well mixed, and a little cooled, the cloth may be dyed therein as usual; but without any other preparation than that of scouring and moistening. To sadden and darken the colour still farther, a little sumach, (*rhus coriaria*,) may be added with the bark; and on the other hand, the colour may be inclined to the olive and yellow, by diminishing the quantity of sulphate of iron, and employing with it a little alum and chalk; or (which is better) a little sulphate of copper, with or without a small proportion of chalk. Or the cloth may be first turned a few times through a vessel, with boiling bark liquor, then taken out, and turned briskly through a vessel with hot water, in which a suitable proportion of sulphate of iron has been dissolved, with or without either alum and chalk, or sulphate of copper and chalk, as the particular colour

intended to be given may require. In either way the colours will prove lasting, and the expence very small; four or five pounds of bark being generally sufficient to dye one hundred pounds weight of cloth, of the colours in question. Cloth prepared by previous boiling, with one twentieth of its weight of sulphate of iron, and one fourth of that quantity of chalk, and then dyed in bark liquor, became of a strong durable chocolate colour; but in this way great care is necessary to render the colour even.

Cloth prepared by boiling with a twentieth of its weight of sulphate of iron, half as much sea salt, and one fourth of that quantity of chalk, and then dyed with bark, received a very lasting dark brown colour.

Cloth dyed with Quercitron bark, sulphate of iron, and sulphate of manganese, in small proportions, became of a light but pleasing drab colour; which, by the addition of a little chalk, was afterwards changed to the cinnamon.

Cloth prepared with nitro muriate of gold, and dyed with bark, became of a delicate olive tinged yellow. The solutions of bismuth, zinc, antimony, silver, mercury, lead, and platina, by different acids, produced various shades of brown, yellowish brown, brownish yellow, cinnamon, drab and olive colours; of which it is not expedient to give my readers a particular description; because they either may be all more cheaply obtained by other mordants, or are not likely to be brought into use.

Cloth

Cloth boiled in water, with one twentieth of its weight of sulphate of lime, and dyed with Bark, received a strong nankeen colour. Nitrate of lime in this way, produced a nutmeg brown; and the muriate of lime produced a very full and lasting drab colour, which in some respects may be preferable to the drabs given by an iron basis, and especially as being less likely than the latter to injure the texture of the cloth.

Of the Properties and Uses of Quercitron Bark in dying upon Silk.

ALL the different shades of yellow, commonly dyed upon silk from weld, may be obtained with equal facility and beauty, and more cheaply, by employing the bark in its stead, after the rate of from one to two pounds for every twelve pounds of silk, according to the particular shade of colour wanted. For this purpose the bark, powdered and tied up in a bag, should be put into the dying vessel whilst the water is cold, and as soon as it becomes a little more than blood warm, the silk, previously alumed, should also be put in and dyed as usual; and where the higher yellows are wanted, a little chalk or pearl ashes may be added towards the end of the operation, as mentioned for the dying of wool.

Where shades of yellow more lively than any which can be given either by weld or bark with the aluminous basis only, are wanted, it will be advantageous to employ a little of the murio sulphate of tin; and but a little of it, because the

calx of tin, unless sparingly used, always diminishes the glossiness of silk.

To produce the shades in question, it will be sufficient to boil after the rate of four pounds of bark, with three pounds of alum and two pounds of murio sulphate of tin, with a suitable quantity of water, for ten or fifteen minutes, and the heat of the liquor being afterwards reduced so that the hand can bear it, the silk is to be put in and dyed as usual, until it has acquired the proper shade, (which it will do speedily,) taking care, however, to agitate the liquor constantly, that the colouring matter, which would otherwise subside in a considerable degree, may be kept equally dispersed through the liquor. By adding suitable proportions of sulphate of indigo to this yellow liquor and keeping it well stirred, various and beautiful shades of Saxon green may be dyed in the same way very equally and cheaply. The Shades intended to incline most to the yellow should be first dyed, and afterwards, by adding more sulphate of indigo, those partaking more of the blue may be readily produced; and indeed nothing can be more commodious or certain than this way of dying the most beautiful Saxon greens upon silk.

By dissolving different proportions of copperas or copperas and alum, in the warm decoction of bark, silk may in the same way be dyed of all the different shades of olive and drab colours; and other varieties may be produced with the bark generally, by employing the same means which are used to produce the like variations with weld.

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*Of the Application of Quercitron Bark to the
Fibres of Linen or Cotton, either woven or
spun, by general Dying.*

I here use the term *general* dying as opposed to that *partial* or *topical* application of colours on which callico-printing chiefly depends. At pages 62 and 63 of this volume I have endeavoured to explain the causes which render adjective colours less durable on linen and cotton than they are on wool or silk, so far, at least, as these causes depend on differences in the structure and chymical properties of the substances in question; but whether my explanation be well founded or not, this at least is certain, that the attraction between the aluminous basis, and the fibres of linen and cotton is much weaker than that which subsists between the same basis, and the fibres of wool or of silk; and this want of a sufficient attraction or affinity has made it necessary to employ extraordinary means for precipitating the alumine more copiously, and fixing it more firmly than it otherwise would be precipitated and fixed upon the fibres of linen or cotton, in order to enable them to receive permanent adjective colours by dying. The principal of these means are certain oily and animal matters joined to some vegetable astringents, particularly galls; all of which, I mean the former, as well as the latter, evidently possess a strong attraction for alumine, and when united to linen or cotton, produce very beneficial effects, as is manifestly seen by the process for dying the Adrianople or Turkey red, concerning which both Mr. Henry and Mr. Berthollet

Berthollet have published several very ingenious as well as highly interesting observations; and perhaps I may be able to add something to these when treating of this subject in my next volume; at present, however, I shall only notice these extraordinary means so far as they seem likely to improve the beauty and durability of the colours, capable of being communicated to linen or cotton from Quercitron bark.

The fibres of linen or cotton when spun or woven are prepared for the dyer by being first boiled in water with a suitable portion of potash, (which for linen should be made caustic, in order that it may act more strongly upon the oily and resinous matters abounding in flax,) and afterwards bleached by exposure upon the grass to sun and air. But as this operation commonly leaves a portion of earthy matter in the linen or cotton, which, by being unequally distributed, would render any colour given by dyeing unequal; the cotton or linen ought to be soaked or steeped in water, soured by sulphuric acid, to dissolve and remove this earthy matter, taking care afterwards to wash or rinse off the acid, lest, being concentrated in the cloth or yarn when drying, it should injure the texture.

The method prescribed by the French regulations, and adopted in most European countries, for dyeing yellow upon linen or cotton from the weld plant is, by soaking the cloth or yarn in a liquor made by dissolving one-fourth of its weight of alum in as much water as is necessary for that purpose; to which it will be highly advantageous to add after the rate of one pound of clean potash,
or

or ten ounces of chalk, for every six or seven pounds of alum (1) to neutralize the excess of acid contained in the alum, and promote a separation of its earthy basis. The cloth or yarn having been thus soaked, is taken out of the alum liquor, and well dried; and being afterwards rinsed, it is to be dyed in weld liquor made by boiling about one pound and a quarter of the plant for each pound of cloth or yarn; which, after having received a sufficient body of colour, is to be taken out of the dying liquor, and soaked for an hour and more in a solution of sulphate of copper (blue vitriol) containing after the rate of three or four ounces of the latter for each pound of cloth or yarn; it is then to be removed, and without being washed, put into a boiling solution of hard soap, containing in like manner three or four ounces of soap for each pound of cloth or yarn, in which it is to be well stirred and boiled for about three quarters of an hour or more, then washed and dried. I have found by repeated trials that this mode of precipitating the calx of copper upon the yellow previously dyed from weld with an aluminous basis, renders the colour more durable, but at the same time gives it a darker complexion. And I have found similar effects where bark was used instead of weld; the colour dyed with the bark in this way having proved in every respect as good as that obtained from

(1) Hauffman says, that when English alum is dissolved in five times its weight of water, and one eighth of its weight of chalk is added to saturate the excess of acid, a solution will be produced which does not crystalize in Summer, and but little in Winter; though without chalk it requires sixteen times as much water as of alum to make a permanent solution.

from weld: but I am convinced, that whether the colouring matter be taken from the former or the latter of these vegetables, the yellow dyed in this way never is either so beautiful or so lasting as that partially given by callico-printers from the same vegetables, and which the dyers might readily give with equal perfection, by only employing the acetite of alumine, or aluminous mordant, described at pages 176, 177, and 178 of this volume; and this more cheaply as well as more expeditiously than that produced by following the French regulations; considering the expence of so much blue vitriol and soap as they require, and which may be rendered unnecessary by adopting the calico-printer's aluminous mordant.

The best method of applying the aluminous mordant for general dying with Quercitron bark (which I most earnestly recommend whenever bright and durable yellows are wanted,) is as follows, *viz.*

Take a sufficient quantity of the acetite of alumine, which for this purpose may be made by dissolving after the rate of *only* one pound of sugar of lead and three pounds of alum, as at page 177, excepting only that it need not be thickened, and mix this liquor with an equal quantity of warm water, then let the linen or cotton (properly cleansed as before mentioned) be thoroughly wetted and soaked in the mixture, which ought to be about blood warm, for the space of two hours, then taken out and moderately pressed or squeezed over a proper vessel to collect what might otherwise drop or run off, and prevent an unnecessary waste of the aluminous liquor; and this

this being done, let the linen or cotton be well dried in a stove heat, where it can be conveniently applied, and then soaked again in the aluminous mordant, and again pressed or squeezed and dried as before; after which, without having been rinsed, let it be thoroughly wetted in as much, and only as much lime water as will conveniently suffice for that purpose, and afterwards dried; and where a very full, bright, and durable yellow is wanted, it may be well to soak the linen or cotton a third time in the diluted aluminous mordant, and after drying, wet it a second time with lime water, and dry it again: but in either case, the linen or cotton after its last dying, should be well rinsed in clean water, in order to separate any loose or unfixed particles of the mordant or basis, which otherwise might do harm in the dying vessel. The lime-water employed in this way, answers the purpose of producing a more copious deposition of the alumine in the fibres of the linen or cotton, and it moreover superadds a portion of calcarious to the aluminous basis; an effect which is not without considerable utility.

I have found, that when the aluminous liquor has been employed at a scalding heat, the colour afterwards produced was not so good as what results from liquor only made blood warm; the pores of linen and cotton being so open as not to require any distension by a greater degree of heat.

The cotton or linen being prepared and rinsed as before mentioned, a small fire is to be lighted under the dying pan or vessel, previously supplied with the usual quantity of water, and the powdered

dered-Quercitron bark tied up in a bag, after the rate of from twelve to eighteen pounds for every hundred pounds weight of linen or cotton where full bodied yellows are wanted, is to be put in, whilst the water is cold, and immediately after it the linen or cotton is also to be put in, upon sticks if it be thread or yarn, or, if piece-work, on the winch, agitating or turning it in either case as usual for the space of an hour or an hour and a half, during which the water should gradually become warm, but not warmer than the hand can bear. When this time has elapsed, the fire may be increased, and the dyeing liquor brought to a scalding and thence to a boiling heat; in which it will be sufficient to let the cotton or linen remain a few minutes only, when a bright lively yellow is wanted, because longer boiling always gives the yellow a brownish cast, whatever vegetable may be employed in dyeing it. The linen or cotton having thus acquired sufficient colour, is to be taken out, rinsed and dried as usual.

When the colour of Quercitron bark is slowly raised in this manner by a very moderate heat, the colouring particles seem to adjust themselves more accurately and unite more intimately to those of the basis, and thereby to produce a colour more fixed and durable than it is when they are hastily accumulated by a boiling heat, and perhaps chiefly upon the surface of the substance dyed and of the basis combined therewith.

All the different shades of yellow may in this way be dyed from Quercitron bark; if it be used sparingly, with a very moderate heat, and the operation

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operation continued only for about half an hour, a pale though lively yellow will result; if used more copiously, and the operation continued somewhat longer, a fuller colour will be produced; and this may be raised higher and higher according as the heat and proportion of bark are increased and the dying operation prolonged, so as indeed to produce a very dark brownish yellow if the liquor be made to boil for half an hour.

Pieces of cotton having been prepared with the printers' aluminous mordant and lime water, as already described, were dyed one with bark and another with weld, and being taken out of the dying liquors, a bit was cut off from each and the remainder put back again into its liquor, in which a small quantity of sulphate of copper had, in the mean time, been dissolved, after the rate of one ounce to five pounds of cotton; and the liquors being nearly of a scalding heat, in about ten minutes the pieces were again taken out and found to have acquired a brownish complexion; but being exposed to the sun and air along with the bits which had been cut off before the sulphate of copper was added to the dying liquors, the brownish complexion of the former soon disappeared, and their remaining colour at the end of four weeks proved to be rather better than that of the bits dyed without the sulphate of copper. It seems therefore probable, that a sparing use of the latter in this way, may contribute something at least to the durability, if not to the beauty of yellows dyed upon linen or cotton, *after* the application of acetile of alumine and of lime as before directed.

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When the aluminous mordant is employed without any addition of water, it may be sufficient to soak the cotton therein *once* only, and after dying to immerse it *once* in lime water, then dry, rinse, and dye it as before mentioned. I think, however, that better effects result from the application of a more diluted mordant, *at two different times*; and indeed I have found, that by immersing the cotton *a greater number of times* alternately in the diluted aluminous mordant and in lime water, and drying it after each immersion, the colour always acquired still more body and durability.

At page 183 I have remarked, that by the East Indian method of callico-printing, the want of acetile of alumine is supplied by impregnating cotton with the astringent matter of yellow myrobalans, and with certain oily and animal substances, which enable the cotton, when a solution of alum is afterwards applyed to it, to decompose and imbibe a larger portion of alumine: and this practice may be imitated in dying the Quercitron yellow upon cotton, with so much advantage as to render the acetile of alumine in a great degree unnecessary, at least where the yellow is not required to be very clear and bright.

Instead of myrobalans, (which are, however, to be found here,) the Aleppo galls may be employed, choosing always the whitest for this use, because the browner might stain the cotton, so as to render it incapable afterwards of receiving a bright, clear yellow; and perhaps in this respect the roots of at least two or three species of North American

American sumach, particularly the *Rhus Glabra* Lin. might be preferable even to the whitest galls, by communicating less stain and producing equally good effects, as I have found them to do in repeated trials.

The best method of employing galls for this purpose is, I believe, to boil after the rate of one pound of them coarsely powdered, with half a pound of Barilla, for the space of one hour, in two or three gallons of soft water, and then straining off the decoction to macerate the cotton an hour or two therein: barilla, or rather the soda which it contains, enables the water to extract the astringent matter of the galls much more copiously than it otherwise could do; and being itself imbibed by the cotton, it also occasions a more plentiful deposition of alumine, when the cotton is afterwards put into a solution of alum, which, for this use may be made by dissolving eight pounds of alum and one pound of chalk in six gallons of water. In this calcarious solution of alum, the cotton, after being taken out of the decoction of galls and dried, is to be soaked for two hours, then taken out and dried; then soaked a few minutes in lime water, and having been again dried, it is to be immersed a second time in the calcarious solution of alum; after which, being again dried and well rinsed, the cotton is to be dyed slowly with the *Quercitron* bark, as before directed. In this way very full bodied and lasting yellows may be obtained, which will bear repeated washings with soap, as well as exposure to sun and air; and the action not only of strong vinegar, but of the oxygenated muriatic acid.

By dissolving after the rate of one pound of hard white soap and half a pound of barilla in three gallons of water, and macerating the cotton therein, as directed to be done with the decoction of galls and sumach, then drying and immersing it in the calcarious solution of alum, and afterwards proceeding, as just directed to be done after such immersion, I obtained a colour (with the bark) nearly as durable as when the decoction of galls had been used, and with the advantage of its not being thereby *darkened*.

A pound of the yolks and whites of eggs having been first beat up with an equal quantity of brown sugar, and then with two gallons of water, and cotton having been soaked therein, instead of the solution of soap and barilla, then dried and immersed in the calcarious solution of alum; dried again and immersed in lime water, and then in the solution of alum, and afterwards rinsed and dyed with bark, as already described, it received a very full and lasting though darkish yellow colour. The animal mucilages in general, and some of the vegetable, being dissolved in water and applied to cotton in the same way as the yolks and whites of eggs just mentioned, produce the like good effects, and more especially the animal glues, which appear to unite both with the cotton and the aluminous basis when used in this way.

A considerable time has now elapsed since I was induced to try the effects of alumine combined with other acids besides the sulphuric and acetic, and also with potash, soda and ammoniac, both in their mild and their caustic states, as a basis or mordant for the Quercitron colouring matter.

matter. To separate alumine from the sulphuric acid with which it forms common alum, this last compound may be dissolved in about eight times its weight of clean boiling water, and mixed with a filtered lixivium of clean potash, which should be added to the solution of alum gradually, until it no longer makes the liquor turbid, or occasions any farther precipitation of alumine. The whole of the mixture may then be put into a canvas strainer to separate the fluid part, and this having been done, boiling water may be poured repeatedly upon the remaining moist alumine, and suffered to run through the strainer until the saline part of the mixture shall have been washed away, as far as it is capable of being washed away by water; the alumine being then taken out and dried, will generally be found to weigh about one fifth part of the weight of the alum employed to produce it: when thoroughly dried, the alumine contracts or shrinks greatly, and becomes at length so hard, that neither strong sulphuric or nitric acids can dissolve it, except with great difficulty and very slowly; and for this reason it ought always to be employed in a moist state when intended to be again dissolved by any acid or alkaline menstruum. Perhaps the great disposition of this earth to contract or shrink by drying, may be one reason why it is generally most advantageous to convey and fix the particles thereof as a basis in the pores of linen or cotton, *first* separately, and afterwards when they have shrunk by drying, to superadd the adjective colouring matter, which may then find more space, and combine with the alumine in greater proportion than it could do when both previously united, were applied together, whilst the particles of alumine were enlarged by moisture.

If moist alumine obtained in the manner just described, be dissolved in either the nitric or muriatic acids, it will by evaporation afford crystals; and those obtained with the nitric acid, by attracting moisture from the atmosphere, will prove deliquescent, unless kept in a vessel closely stopped. M. Berthollet found, that in these cases, the crystals depended on a remnant of sulphuric acid, which always adheres to alumine when separated in the way just described; and that by afterwards digesting it for some time in a solution of potash, or of ammoniac, this adhering sulphuric acid might be decomposed; and that the alumine being then dissolved either in the nitric or the muriatic acid, no crystals were produced. It must, however, be remarked, that the alumine mentioned to have been employed in the succeeding trials, was obtained in the way first described, and therefore was not completely divested of sulphuric acid,

Having boiled a suitable portion of moist alumine with a decoction of Quercitron bark during the space of half an hour, I attempted to dye both wool and cotton therewith, in order to see whether the undissolved particles of alumine, so united to the colouring matter of the bark, would become the basis of a lasting colour. I found, however, by repeated trials, that cotton in this way could only be made to imbibe a pale yellow, which probably adhered to the surface only of its fibres, because it was nearly destroyed by a single week's exposure to the sun and air. Wool, however, in this way received a brownish yellow of sufficient body and considerable durability.

Ammoniac,

Ammoniac, or volatile alkali, whether mild or caustic, appears to dissolve alumine so very sparingly, that hitherto I have found no considerable benefit from any solution of this kind as a mordant. Nor have I succeeded much better with either the carbonated (mild) potash, or that of soda, their action not being considerable upon the earth of alum. But if this earth, obtained by precipitation and washing as before mentioned, be digested whilst moist with a strong lixivium either of potash or of soda, in its pure or caustic state, in a mattrass placed on a sand heat, nearly approaching that of boiling water, it dissolves very copiously, and may afterwards, by evaporation, be made to crystalize. The celebrated Macquer appears to have believed that very beneficial effects might be obtained in dying by these combinations, and more especially when used as mordants for the madder red on cotton. It seems evident, however, that he was greatly mistaken respecting the true nature of those operations upon which this belief was founded; and that in the process for Turkey reds, where he supposed the durability of colour to result principally from a combination of this kind, no solution of aluminous earth by any alkaline menstruum could have taken place; and though Mr. Hauffman appears also to have formed considerable expectations of advantage from the application of these solutions of alumine by potash or soda, I have been led by the results of many trials, to concur in opinion with Mr. Berthollet, that but little good is to be expected from them, unless it be under the circumstances which I shall presently explain, because the alkaline menstruum evidently has too much affinity to the

particles of alumine to allow of their being deposited and fixed in the substance, to be dyed so copiously as is necessary; and I have repeatedly found, that after having soaked cotton a sufficient time in the diluted solution of alumine by either potash or soda, the basis was almost wholly carried off or removed by only rinsing the cotton in water to fit it for being dyed, and that only very feeble colours could be raised upon what remained of the alumine as a basis. This was more especially the case where the solution of alumine had been made by potash, which by attracting moisture from the atmosphere, rendered it difficult to dry the cotton sufficiently when impregnated therewith, at least without artificial heat. These defects were, however, removed, and a *very excellent durable yellow* produced by putting the cotton which had been *first* soaked in a diluted solution of alumine by potash, into water which had dissolved as much common alum as it could retain, whilst blood warm, macerating and turning it therein for the space of half an hour, (during which the potash and sulphuric acid combining, each precipitates the alumine of the other,) then drying the cotton, and afterwards immersing it in lime-water; then drying again, rinsing and dyeing it with the bark as before directed. The yellow given in this way faded but very little by two months exposure to sun and air in the midst of the Summer; nor was it sensibly weakened by the action of strong French vinegar, or of the oxygenated muriatic acid. The solution of alumine by soda produced equally good effects in this way.

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Nitrate of alumine (made by saturating the nitric acid with moist alumine as before mentioned,) being dissolved in eight times its weight of water, and used instead of the solution of common alum last mentioned, produced a yellow rather better and more durable even than the last. Cotton which had received no impregnation, being macerated in a like solution of the nitrate of alumine, then dried, immersed in lime water, rinsed and dyed with the bark, received a yellow considerably better than I could obtain with a solution of common alum in the same way.

Muriate of alumine generally produced with the bark, effects as good, but not materially better than those resulting from common alum used in the same ways.

In dying any of the yellows before mentioned with bark, the colour may be raised to an orange by employing a suitable proportion of madder along with the bark.

It can hardly be necessary for me to mention, that linen or cotton, either spun or wove, when previously dyed blue of a suitable shade in the usual ways, will be rendered green by superadding the Quercitron yellow in the ways, and by the means already directed for dying this yellow upon linens and cottons not previously made blue, taking care to proportion the quantum or body of each of the component blue and yellow colours to the particular shade of green which they are intended to compose or produce.

Linen and cotton soaked four hours in a mordant made by dissolving lime in muriatic acid,
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and mixing the solution with six times its weight of water, afterwards dried, rinsed, and dyed with Quercitron bark, took a full drab colour which resisted the action of sun and air for a considerable time: but neither the sulphate nor the nitrate of lime employed in this way with the bark, gave any thing more than buff or slight nankeen colours of little durability.

Magnesia dissolved by the sulphuric, the nitric, muriatic, and acetic acids, and used in this way as a mordant, produced, with bark upon linen and cotton, weak drab, cinnamon, and nankeen colours, which, however, proved too fugitive to be of any use.

Cotton soaked in a diluted solution of flints, made as mentioned in a former part of this volume, and afterwards rinsed and dyed with the bark, became of a nankeen colour somewhat lasting.

Among the metallic bases, that of tin might naturally be expected to produce the most beneficial effects by *general dying* upon linen and cotton with the Quercitron bark; but hitherto my experiments therewith, though they have been very numerous and greatly diversified, afford no successful results: for though different solutions of tin, (particularly the nitro-muriatic and the murio-sulphuric,) when diluted and applied as mordants to linen and cotton, enable these substances afterwards to imbibe yellows exceeding all others in brightness, lustre, and beauty; and though these yellows are capable of resisting the action of boiling soap suds, as well as of strong acids,

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acids, not excepting the oxygenated muriatic acid, yet they decay very speedily when exposed to the sun and air, so as even to suffer more in a single week than the Quercitron yellows dyed upon an aluminous basis commonly suffer in a month. The tin basis is, moreover, accompanied with this *singular* circumstance, that when applied separately to the linen or cotton intended to be dyed, and when these substances, after the usual drying and rinsing, are dyed with the bark, the colour, (contrary to what happens with the aluminous basis,) proves much more fugitive than it does when the solution of tin and decoction of bark are first mixed together, and afterwards applied to the linen or cotton profubstantively; nor have I ever been able to apply any of the solutions of tin even in small quantities mixed with an aluminous mordant upon linen or cotton, without perceiving that the colour afterwards obtained thereby from bark was much less durable in respect to sun and air, than it would have been with an aluminous basis only. I shall, however, abstain from giving any opinion respecting the cause of these defects, until the results of some nice and difficult experiments, which successive interruptions have hindered me from bringing to a satisfactory conclusion, shall enable me to do so on better grounds than I possess at present.

Zinc dissolved by different acids, and employed as a basis for dying with Quercitron bark on linen and cotton produces brownish yellows, inclining more or less to the olive and drab colours; they seem, however, less durable than the like colours, which may be more conveniently
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and cheaply given by substituting solutions of alum and of iron, mixed in different proportions, as mordants.

Bismuth being dissolved in nitro muriatic acid, and the solution afterwards sufficiently diluted by water, and cotton being soaked therein for two hours, then immersed in lime water, dried, rinsed, and dyed with Quercitron bark, it took a very high and full, but at the same time a very brownish yellow, of considerable durability.

Copper dissolved in the sulphuric, the nitric, muriatic, and acetic acids, and afterwards sufficiently diluted with water, being applied to linen and cotton as a mordant, enables them to obtain from Quercitron bark by dying, different shades of full but brownish yellow, which, however, does not long bear washing with soap, or exposure to rain, sunshine, and air; the oxyd of copper, on which the colouring matter is applied, being readily acted upon by all these agents. Soaking the linen or cotton in lime water when impregnated with the oxyd or solution of copper, previous to the dying with bark, renders the colour more durable.

Cotton having been soaked two hours in a diluted ammoniate of copper, and then hung out to dry, appeared at first of a fine blue colour, but afterwards became of a very beautiful bluish green. A bit of this cotton being dyed for a few minutes in a decoction of Quercitron bark, became of a fine yellowish green: another bit dyed in the same decoction for a longer time became of a dark brownish yellow colour; this was, however,

ever, changed to a lively yellowish green, by washing with soap, and suffered but little during three weeks exposure to sunshine, air, and rain.

Linén or cotton soaked in a diluted nitrate of lead, then in lime water, and afterwards rinsed and dyed with Quercitron bark, took a kind of nankeen brown colour somewhat, though not very, durable.

The other solutions of lead appear to be still less useful as mordants upon cotton for dying with the bark.

Manganese being dissolved by a very weak or diluted sulphuric acid, and the solution afterwards mixed with an additional portion of water, cotton was soaked therein for two hours, and afterwards immersed in lime water, then rinsed and dyed with the bark, from which it obtained a nutmeg brown colour inclining slightly to the olive, which proved somewhat lasting.

The oxyd of arsenic is capable of serving as a mordant for the Quercitron colouring matter, but as the shades produced by it may be obtained by cheaper and much less dangerous means, I cannot recommend its use for this purpose.

Cotton soaked in a diluted nitro muriate of gold, afterwards rinsed and dyed with Quercitron bark, received a delicate olive tinged yellow of considerable durability; but this mordant
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is much too expensive to be used in this or in almost any other way.

Cotton first dipped in a weak solution of soda, became of a yellowish brown by being soaked in a diluted solution of platina by the nitro-muriatic acid, and being afterwards dyed with the bark, it became of an olive colour.

Cotton dipped in a weak solution of soda, and then in a diluted solution of the grey ore of Cobalt, (*Cobaltum Galena*,) in the muriatic acid, became first green and then yellow; and this being afterwards dyed with Quercitron bark, the colour changed to a lasting black. The pure Cobalt, dissolved either by the muriatic or the nitric acids, and applied in this way to cotton, produced a cinnamon brown colour, with the Quercitron bark.

Cotton wetted with a solution of soda, and then with a diluted nitrate of nickle, became green, and being afterwards dyed with the bark, it became of a full cinnamon brown.

Iron, though I mention it last, seems to be the most useful of the metallic bases for dying on cotton and linen with the Quercitron bark, and more especially for producing the drab, mud, dove, and olive colours, with the great variety of shades which result from a mixture of these upon cotton velvets, veverets, fustians, &c. These colours have hitherto been commonly dyed from what is called the old fustic, (*morus tinctoria*,) though they may be given more cheaply and conveniently with the Quercitron bark in the same

same ways, and when so given, are more lasting than those given by fustic, as I have repeatedly found by exposing samples of each to rain, sun, and air, for the space of six months together.

The cheapest form in which iron can be employed in this way, is that wherein it is dissolved by sulphuric acid, as in the common sulphate of iron or green copperas; and after many trials I have not found any other combinations of this metal capable of producing effects so much better in dying as to compensate for the increased expence attending their use. Copperas and Quercitron bark, in different proportions, produce all the different shades of the *drab* colour, from the deepest to the lightest; and for this purpose, the copperas may be either dissolved in a decoction of the bark, and the pieces of cotton velvet, velveret, or fustian turned through the liquor (of a suitable heat) by the winch, or the bark may be boiled with water in one vessel and the copperas dissolved by warm water in another, and the pieces passed as usual, first through the latter and then through the former, and so alternately from one to the other, until the proper shade is acquired; and by adding after the rate of one pound of chalk to eight pounds of copperas in the vessel wherein this last is dissolved, the colour will be rendered more durable, and at the same time changed a little to the chocolate brown.

To produce the olive shades, sulphate of copper (blue vitriol) with about one-eighth part of its weight of chalk, or alum with a like proportion of chalk, may be employed along with the copperas,

peras, so as to give the drab colour a sufficient inclination towards the yellow hue; and for this purpose the blue vitriol is, I think, preferable to alum.

For the drab colours, one or two pounds of copperas, according to the fullness of colour wanted, with about three times as much bark as of copperas, and a little chalk, will suffice to dye 100lb. weight of velvet, velveret, or fustian: and for the olives, it will only be necessary to diminish the quantity of copperas according as the shade is wanted to incline more or less to the yellow, and add as much or a little more blue vitriol in its stead: and for this purpose the blue vitriol may be either dissolved in the same vessel with the copperas (and chalk,) or it may be dissolved with chalk in a separate (third) vessel, and the velvets or fustians, after they have been turned or worked sufficiently, in the two first vessels, containing, one the copperas liquor, and the other the bark liquor, may be turned or worked in the solution of blue vitriol in the third vessel, until it inclines sufficiently to the yellow hue; and perhaps this method will generally be found most convenient to fustian dyers, who are frequently required at the same time to dye a great variety of different shades. But otherwise it probably would be most advantageous to turn and soak the pieces for a little time in the solution of copperas and chalk, or of copperas, chalk, and blue vitriol, (or alum instead of blue vitriol,) then immerse them for a few minutes in lime water, and afterwards rinse and dye them in a decoction of bark, by which, colours much more lasting and much less liable to spot than those commonly obtained, might be dyed; it would, however, be more difficult in
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this way to produce that great variety of shades, which in the other are easily attained by any dyer accustomed to the use of old fustic for the like purposes, as I well know by my own experiments and by those of others. One pound of bark will commonly produce as much effect as four pounds of old fustic.

When darker colours are wanted, than can be conveniently given with the Quercitron bark and copperas, a portion of Spanish sumach may be added to obtain them, as is done for saddening the colours given with old fustic and copperas; though it is possible to produce a durable colour, approaching very nearly to a *perfect black*, by the Quercitron bark and the iron basis, by first soaking the cotton in a weak solution of barilla and liver of sulphur, then drying and immersing it in a diluted solution of iron, by the nitro muriatic acid, and afterwards dying it with the bark.

Of the Application of Quercitron Bark in Topical Dying or Callico Printing.

Between the 170th and 179th pages of this volume, I have given a general though summary account of the art of callico printing, as practised during many ages by the inhabitants of India; and also of the improvements which have followed the introduction of this art into Europe. I have also particularly described the two principal mordants or bases employed to fix and raise the different adjective colours, by topical or partial dying; I mean the printers' aluminous mordant or acetite of alumine, and what is called iron liquor (acetite of iron), made by

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dissolving that metal in vinegar, four beer, &c. These mordants the callico printers have very improperly named colour or colours, though they only afford the basis or bases of colour, to be afterwards obtained from madder, weld, Quercitron bark, &c. For an account of the preparation of acetite or sugar of lead, and of the substitutes for it, in making the aluminous mordant, I cannot do better than refer my readers to Mr. Berthollet's chapter on that subject, and to the writers therein mentioned; and, for an account of the true nature and advantage of this aluminous mordant, my readers will be pleased to recur to pages 176, 177, 178, 179 and 180 of this volume. Of the iron liquor, it may be proper to observe, that, when made with vinegar, that which has been longest kept is most esteemed. But of late much is consumed, which has been prepared by dissolving iron more expeditiously in the pyro ligneous acid obtained by distillation from wood and from tar; and it is probable that, in some cases, the action of this acid has been strengthened by an addition of the muriatic, though this last must have a tendency to render the solution corrosive.

Linens or cottons, before they are printed, require to be bleached; and the more perfectly this operation is performed either by the old or new method, the less will the parts intended to remain white be afterwards stained by the madder, weld, or bark liquors in dying; and the more easily will any discolouration from these liquors be afterwards discharged. After bleaching, the pieces will need to be calendered, in order to produce a smooth surface, and render

the woof and shoot as even and square as possible, and thereby favour a due application of the mordants; which, being first properly thickened by starch, flour, or gum, as formerly mentioned, are to be applied by blocks, plates, cylinders, &c. as those employed in this part of the business sufficiently understand. This being done, the pieces are to be well dried in a stove heat, so as to evaporate the acetous acid, holding the basis in a state of solution, and cause the latter to be more copiously deposited and fixed in the pores of the cloth.

After drying, the cleansing operation follows; and this is performed in a cistern with water, nearly as warm as the hand can well bear, and a quantity of fresh cow-dung; in which the pieces are to be briskly worked, so as to dissolve the thickening of the mordant or mordants, and separate all the unfixed superfluous particles of alumine or of iron, which the cow-dung serves to entangle, so as to hinder them from spreading and attaching themselves to the parts intended to be kept white, and there becoming the basis of a future stain or discolouration, which it might be difficult to remove; after this the pieces, being thoroughly soaked and well rinsed in clean water, will be fitted for dying with the bark.

In many cases, madder colours are to be mixed in the same piece with those of the bark; but in these the madder ought to be first dyed on a separate course of work, in which the mordant or mordants are printed only so far as the madder colours are intended to extend; and the pieces being then dried, cleansed, and dyed with the

madder, and afterwards whitened by branning and bleaching, are to be calendered, and made ready to receive a second course of mordants for the bark, in which the pieces are to be printed, dried, cleansed, &c. as just mentioned.

My readers have been already informed, that the bark produces a good bright yellow with the aluminous mordant, and a drab colour with the iron liquor; and that both together mixed in different proportions, produce different shades of olive and olive-brown colours. And that if a strong decoction of galls be added to the iron liquor, and the mixture applied in the same way to linen or cotton, it will, by dying with the bark, produce a black sufficiently fixed, though inclining a little to a brownish hue. By means, therefore, of the aluminous mordant and the iron liquor, three very distinct colours besides the black are obtained from Quercitron bark: and moreover, by applying the aluminous mordant upon a madder red and an Indigo blue, an orange in the first case, and a green in the second, will be produced when the piece comes to be dyed with the bark.

I have already noticed (at page 186) the practice of colouring the solution of alum, in the East Indies, with sampfan or sappan (red) wood; a practice which the callico printers of Europe have imitated, by colouring the aluminous mordant with Brasil wood, (and thence calling it *red* colour,) not only when it is intended to serve as a basis for the madder red, but also for the Quercitron or weld yellows; though in the latter case at least, the practice ought to be laid aside.

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It is indeed necessary that some tinge should be given to mordants in callico printing, in order that the printer may readily discern the exact progress and extent of his work: but it is much better to give this tinge, from Quercitron bark, to figures or parts intended afterwards to receive the bark or the weld colours by dying, than to give it from Brasil wood; the colour of which, were it to remain, would hurt the true yellow intended to be afterwards fixed upon the aluminous basis: but the false Brasil colour, not having so much affinity with the basis as to be able to maintain its situation, is always dislodged by the superior affinity of the bark or weld. This dislodgment, however, of one colouring matter by the application of another, takes up some time, and unnecessarily prolongs the dying process (the yellow in this case rising more slowly); and the parts intended to be kept white are also rendered liable to a greater degree of stain or discolouration. But, where the mordant has been tinged with the Quercitron bark, a portion of the colour intended to be given is already applied to the basis; and, though at first not perfectly fixed upon the linen or cotton, it soon becomes so in the dying vessel; whilst the additional colouring matter of the bark, having no false Brasil wood colour to dislodge, applies itself without impediment to the aluminous basis, and produces the requisite degree of colour much more quickly, as may be easily seen upon a proper trial.

I do not indeed think that any degree of tinge ought to be thus given, even from the bark, *beyond* what is necessary to enable the workman to see his work with sufficient clearness; because

the particles of alumine or of iron, when previously united to any species of colouring matter, do not seem by cold application to fix themselves either so intimately or so *copiously* in the fibres of linen or cotton, as they do when applied without any such union or incumbrance; and I have repeatedly found that yellow colouring matter, dyed upon an aluminous basis *untinged*, produced a more lasting colour than it does upon a basis previously tinged even by Quercitron bark, and much more lasting than where the tinge had been given with Brasil wood. And this fact will enable us to conceive one at least of the reasons why it is most advantageous, in dying upon linen or cotton, to apply the aluminous basis first by itself alone. But, in topical dying with the Quercitron bark or with weld, wherever it is necessary to give a moderate degree of tinge to the mordant, whether aluminous or ferruginous, (i. e. iron liquor,) or a mixture of these, I must strongly advise it to be given by a decoction of the bark made very strong, that it may not too much weaken the mordant, and at the same time employed as sparingly as the nature of the case will permit. The effect of mordants topically applied, often depends greatly upon their being either too much or too little thickened with gum, starch, or flour, which are usually employed for this purpose. When the liquor has been too much thickened, it does not sufficiently penetrate the fibres or substance of the linen or cotton, and therefore the colour raised upon it proves weaker and less durable than it otherwise would do: but on the contrary, if the liquor be not sufficiently thickened, it runs or spreads too far upon the surface

face of the piece, and produces figures or impressions which prove confused and undefined. In general the liquor for this kind of application should be made so thick, and only so thick, as barely to prevent its spreading beyond the proper limits; and it seems more necessary to catch exactly this point of thickness or fluidity with the iron liquor than with the aluminous mordant, because the oxyd of iron does not combine so intimately as the alumine does with the acetous acid; but, on the contrary, it remains suspended in a less divided state, and neither penetrates so freely nor unites so intimately as the particles of alumine with the linen or cotton to which it is applied; and therefore the iron liquor in particular ought never to be thickened any more than is necessary to hinder it from spreading too far.

When the mordant has been applied, and has had sufficient time to penetrate the substance of the cloth, it should be thoroughly dried in air artificially heated as before mentioned, so as to evaporate not only the water, but as much as possible of the acetous acid united to the alumine, or to the oxyd of iron, in order that nothing may remain to oppose their intimate union with the fibres of the linen or cotton, which the water, and more especially the acid, necessarily would do, by exerting their own particular affinities upon the substances intended to be thus intimately united. It will however be impossible in *this* way to evaporate the *sulphuric* acid, of which the aluminous mordant, made with the usual proportions of alum and sugar of lead, always contains a little; and which, when the pieces

are brought under the cleansing operation, enables the warm water to re-dissolve and separate a part of the alumine, wanted for raising and fixing the colours intended to be afterwards given by dying; which alumine, being so re-dissolved and separated, is apt, even in spite of the viscidty and entanglement of the cow-dung, to fix itself again upon those parts of the linen or cotton intended to remain white, and occasion a much greater and more lasting degree of stain or discolouration than would otherwise take place in the dying vessel. These effects might indeed be obviated, by mixing a little lime or chalk with the cow-dung and water employed for the cleansing, so as to neutralize the sulphuric acid; but, by so doing, a sulphate of lime would be produced; and this, by fixing itself on the parts intended to be kept white, would give them a calcareous basis, and occasion another kind of stain or discolouration as bad as that intended to be thus prevented. But carbonate of pot-ash or mild vegetable alkali, used in this way instead of lime, will answer the purpose of neutralizing the sulphuric acid, without communicating any improper basis of colour, so as to occasion that kind of stain or discolouration which it is so desirable to avoid; though if any more of it be used than what is sufficient barely to neutralize the acid in question, it will exert a mischievous action, by dissolving a portion of the aluminous basis fixed upon the linen or cotton, and render the yellow afterwards communicated by dying more feeble than it otherwise would have been. *A very little* of the mild vegetable alkali may however be used in this way with advantage, so as to leave the pieces capable of receiving full

full strong colours, whilst the parts intended to remain white will be but very slightly discoloured by the dying process, and afterwards easily whitened. The mild vegetable alkali does not dissolve the oxyd of iron, and therefore may be used in this way with less caution to pieces printed only with the iron liquor.

It is in all cases of great importance, that the cleansing operation should be well conducted, and thoroughly performed; but more especially where a large proportion of drab, dove, and olive colours are to be intermixed with yellows; because the oxyd of iron, which serves as a basis to the former, is very apt to attach itself too copiously to the linens or cottons on which the iron liquor is printed; and unless the redundant part be carefully removed in the cleansing operation, (which is a work of some difficulty,) it will remain, and be afterwards attracted and separated by the colouring matter of the bark in the dying vessel; and, uniting therewith, it will give the dying liquor an olive or drab colour tinge, and greatly tarnish the yellow figures or designs, as well as stain the parts intended to be kept white; and, therefore, whenever the iron liquor is to be printed upon the same piece with the aluminous mordant, the former should be diluted as much as it will bear, without making the liquor too weak to afford a sufficient basis for the colour intended to be afterwards dyed upon it. By such dilution, joined to proper care in cleansing, the yellows may be made to come out of the dying liquor perfectly untarnished; which otherwise they will not do, at least when accompanied with any considerable proportion of figures or designs

designs which have been printed with iron liquor.

Having premised thus much concerning the operations of printing and cleansing, I now proceed to that of dying with the Quercitron bark. For this, a suitable portion of the bark, previously ground, is first to be put into a dying pan or vessel with cold water, and the pieces to be dyed immediately after; a small fire is then to be lighted under the pan, so as gradually to warm the water; and, while this is doing, the pieces are to be slowly turned by the winch, in order that the colouring matter may apply itself equally: when the liquor becomes a little more than blood warm, the colours will take sufficiently quick, and prove more lasting than they do when raised more hastily; because in a moderate warmth the colouring particles (as was before observed) have time, and are enabled to adjust themselves more accurately, and unite themselves more closely to the particles of alumine, than they can do when hastily thrown and accumulated by a greater heat upon the printed figures or designs. And I have repeatedly found, that samples slowly dyed with the bark in this way, being exposed to the sun and air along with others dyed more expeditiously in a boiling heat, proved much the most lasting. And if the Quercitron yellow has at any time been found less durable than that of the weld, it can only have been so through some defect in the mode of dying, at least if there was none in the mordant. Hitherto the bark has generally been used with too much heat *at first*. I say *at first*, because after the colour

colour has been slowly raised, by liquor moderately warm, to nearly the proper height, a boiling heat will do no harm, excepting that of occasioning a little more stain or discolouration upon the parts intended to remain white; and though the avoiding of this is an additional motive for applying the bark in water of a moderate warmth only; yet this of itself might not be a very powerful motive, because such stains from the bark are much more easily removed than those resulting from weld. But the most essential difference between these vegetables, respects the degree of heat by which their several colours are most permanently fixed upon linen or cotton; that of weld requiring at least a scalding if not a boiling heat to render it lasting, whilst the bark colour, as has been already observed, proves most durable when applied in water but little more than blood warm. And indeed I have found, during the Summer months, that cottons printed with the aluminous mordant were able to imbibe a good, though not a very high yellow, by only remaining a few hours with bark in water of the heat of the open air, (in which it was placed,) and without any perceptible stain or discolouration upon the parts not printed. A piece of the callico so dyed in the heat of the atmosphere only, being cut off and farther dyed with the bark in boiling water, it imbibed a greater body of colour; but a sample of this and of the former or paler yellow being equally exposed to the sun and air, I found at the end of three weeks, that the latter, which had been the deepest, retained no more body than the other; the additional colouring matter, which in a boiling heat had been enabled to apply itself upon the aluminous basis, having

having been all discharged during this exposure to the weather. A fact which seems to indicate, that when the alumine has attracted to itself a certain portion of colouring matter, any addition made to it afterwards by the aid of heat, will be less permanently fixed, and therefore liable to be more speedily removed by any of the causes which usually contribute to the decay of colours.

All the different shades of yellow may be obtained from the Quercitron bark by varying the quantity, and applying it with greater or lesser degrees of heat during a longer or shorter time. By using the bark sparingly in water only blood warm, pale delicate yellows may be raised in about fifteen or twenty minutes, and the parts intended to be kept white will receive scarcely any discolouration; by a larger proportion of bark, and by keeping the pieces for a longer time in the dying liquor, though without increasing its heat, a full and clear lively yellow may be produced; and by a still greater proportion of the bark, and a prolongation of the dying operation in a scalding heat during the latter part of it, the colour may be raised first to a high golden, and afterwards to a very full brownish yellow. The quantity, therefore, of bark to be employed must always depend upon the nature and closeness of the figures or impressions which are to be dyed, and the height or fullness of colours intended to be produced. Commonly, however, one or two pounds of bark will suffice for each piece; but, where too little has been employed at first, a farther quantity may be afterwards added without inconvenience; and, when the dying

is to be performed in a very moderate heat, it will always be most advantageous to employ a little more bark than is necessary; which may be done without any loss of colouring matter, because other pieces may be afterwards dyed, with a farther supply of bark, in the same liquor; and I have found that yellows, whether dyed from bark or weld, commonly prove most durable when the dying liquor has been somewhat plentifully stored with colouring matter; and in general I think it best to employ the bark so freely, as that the liquor may be strong enough without being made more than blood warm, to produce full bright yellows in the space of half or three quarters of an hour; the tinge or discolouration which the parts not printed imbibe from the bark in this way not being half so great as that produced by weld, and it being afterwards discharged with less than half the time and trouble which even an equal degree of stain from the latter would require. Indeed, where the pieces have been at first well cleansed from all loosely adhering and superfluous particles of the aluminous or ferruginous bases, the discolouration from bark generally proves so inconsiderable, that by rinsing or washing them in cold, and more especially in warm water, it may be sufficiently removed without either braning or bleaching, excepting where the unprinted parts are required to be uncommonly clear and white: and when this is the case, I think it best to add after the rate of one pound of cream of tartar, in powder, for every twelve or fourteen pounds of bark, putting the tartar into the water immediately after the bark, and then dying the pieces, as I have already explained. The tartar used in this way

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will

will contribute much towards keeping the white or unprinted parts free from stain or discolouration; and it will, moreover, give the Quercitron yellow that bright, clean, and delicately greenish hue which is sought for in the weld, so as to make the former resemble the latter. But, as the tartar tends to keep the Quercitron yellow from taking so fast or rising so high as it would otherwise do, the liquor may, in this case, be made hotter in the latter part of the operation. On the contrary, if, instead of tartar, one pound of clean white pot-ash be added for every thirty pounds of bark, a very high, and at the same time a very bright yellow will take so quickly, that the liquor should never be more than blood warm: and, though the unprinted parts may seem a little more stained than they are when no pot-ash is used, the stain will be discharged by thoroughly rincing and washing the pieces as usual.

Some callico printers, not acquainted with the best methods of employing the bark, have thought proper to join with it a little of the decoction of weld: I cannot, however, recommend this practice, because in truth the bark, when properly used, wants no such assistance, and because the colouring matter of the weld does not take permanently without a greater degree of heat than ought to be employed with the bark. It moreover occasions a much greater stain upon the unprinted parts, and at the same time degrades the madder reds and purples, (where these colours have been previously dyed,) much more than the bark.

It

It is to be observed, that the very moderate warmth, which best suits this kind of dying with the bark, does not, in general, completely extract its colouring matter, at least from such parts thereof as are not finely ground; but, being tied up in a bag, it may be afterwards boiled separately in water, and the decoction so made may be employed for dying olive and drab colours, where they are not intermixed with yellows, or reds. Some callico printers have, indeed, thought it best, in all cases, to begin by boiling the bark in a small quantity of water, so as fully to extract the colouring matter, and then, for yellow as well as drab and other bark colours, to put a suitable proportion of the decoction into the dying vessel, with clean warm water, and dye the pieces therein, adding more of the decoction as wanted from time to time. I do not, however, think this practice so convenient as what I have recommended.

A very ingenious printer in a distant country and warm climate, some time since favoured me with an account of his method of using the bark, which he considers as one of the best: "I pound (says he) the bark, and boil it in a good quantity of water, say twenty-five gallons to seven pounds of bark; after which I let it settle, and pour off the clean decoction; of which I add a portion to a tub full of clean cold water, and immediately, with the hand, pass a quantity of clean rinsed (printed) cloths through the water; they take on colour very quickly, and it appears fresh and beautiful: I then add another portion of the decoction, and bring out a pretty full yellow; meanwhile I have my large copper ready with

with clean water as warm as the hand can well bear, and to this I add also a portion of the decoction; and then remove the cloths from the tub into the copper, and turn them quickly round; by which method I obtain the best and most durable yellows: ten or fifteen minutes will be long enough to keep the cloths in warm water, where a delicate yellow is required." "I found it easy," continues the writer, "to manage the olive and drab colours in the copper; for *these*, I use the bark which has been once boiled for the yellow; seven or eight pounds of it are to be boiled in twenty-five gallons of water, and then the whole is to be thrown into a copper containing about 250 gallons; through which I pass about 225 yards of cloth perfectly well rinsed, or, if it be heavy work, only about 180 yards, which are to be turned quickly round: I begin with a moderate fire, which in half an hour is to be raised so as to make the water almost boil. Here, and especially for *dove* colours, I use a little furnach, which requires considerable heat before it produces any good effect; and therefore I think it useless for yellow, which the bark produces with so little heat. I have seldom allowed more than an hour for such olives, drabs, and doves; and I never join yellows with them, because the grounds will in this way be so much stained as to require more bleaching than the yellows can bear without injury; but doves, olives, and drabs stand the bleaching, and remain unimpaired after the grounds are become perfectly white." This account the writer concludes by saying, "I have been able to do more variety of work with the bark than with any other colouring matter yet known; it is pleasing to work with, as it takes

takes effect quickly, and is very easily managed by any person who knows the business of neutralizing salts, and preparing cloth to receive colour.

The rule which this gentleman seems to have prescribed to himself, of never joining the drab and dove colours to the yellow, is, I believe, much too rigid; for though, in truth, it is impossible to dye perfectly bright yellows where they are intermixed with any considerable proportion of what is called the *black colour*, and difficult to do it where the drab and dove colours abound very much; yet, in the latter case, this difficulty may be very much diminished by using the iron liquor of no greater strength than is necessary, and taking care to have the pieces thoroughly cleansed (as lately mentioned) before they are put into the dying vessel: if this be done, a considerable portion of olive, drab, and dove colours may be intermixed, and even a little of the black, without any material degradation of the yellow. To improve the black, and darken the drab or dove colours, (which the printer is often desirous of doing,) a little Malaga sumach, (*rhus coriara*), in powder, may be advantageously employed with the bark, after the rate of one pound of the former to three or four of the latter. It is, I believe, generally thought best to raise the colours first with the bark, and afterwards change or darken the doves and blacks by adding the sumach, and continuing the process until the desired effects have been produced. My own experiments, however, lead me to conclude, that time may be saved, and every good purpose attained with equal certainty,

ty, by putting the sumach into the dying vessel along with the bark, and thus applying the colouring matters of both at the same time; taking care, however, not to heat the dying liquor beyond what the hand can bear. In this way the parts unprinted may be kept perfectly white, so as never to need either bleaching or branning. The sumach, indeed, when put into the water at the same time with the bark, and used in this way, produces, in an extraordinary degree, the effect of keeping the white or unprinted parts perfectly clear and free from all discolouration; which it probably does by means of a *particular acid* contained in this and many other astringent vegetables: One pound of sumach to three of the bark will be amply sufficient for this last purpose; and in that proportion the sumach will make the parts printed with iron liquor incline towards a purple colour instead of the drab, which Quercitron bark used *alone* would produce.

This change of colour produced by sumach will sometimes render the use of it inconvenient; but when this is not the case, a small proportion thereof joined to the bark, as before mentioned, will prove more effectual than cream of tartar in preventing even the slightest stain or discolouration upon the unprinted parts of cottons topically dyed.

A gentleman, of whose information I have more than once availed myself, some time since brought from Bengal, and gave me a parcel of the dried leaves and tops of a plant there called D'howah, and employed, as he informed me, in the dying of topical or field colours by putting

ting a small quantity of it into the copper when the colours begin to rise, in order to keep the grounds or unprinted parts clear; an effect which, upon trial, I found it produce nearly as well as sumach; and upon dying a bit of cotton which had been printed with iron liquor and the aluminous mordant separately, in a decoction of this plant only, it imbibed colours very nearly resembling those of sumach, though the decoction itself, even when made very strong, did not discover any astringency to the taste.

The berries of the common Pennsylvanian sumach (*rbus glabra*) are covered with a red farinaceous matter, containing a large proportion of an acid which I believe to be the oxalic. These berries employed with the Quercitron bark, after the rate of one pound of the former to twelve of the latter, produced effects nearly similar to those of cream of tartar, as already mentioned, in preserving the unprinted parts of cottons from being stained, and in giving the Quercitron yellow the pale greenish complexion which distinguishes that of weld. Such means cannot, however, be employed where very full high yellows are wanted; and when this is the case, if the grounds or unprinted parts are required to be perfectly clear and white, it may be best to employ a little clean pot-ash in the dying, as lately mentioned, and afterwards to spread the pieces for a day or two upon the grass, laying what is called the wrong side upwards, as is practised with other field colours. Those of madder and weld indeed always require this operation, though it cannot be wanted for those of the bark, except in the single case just mentioned; and then only

for a very short time, unless it be in rainy cloudy weather, when this kind of bleaching proceeds very slowly with all colours, because the action of the air is then not only unassisted by the rays of the sun, but obstructed by the water which it holds in a state of solution.

Messrs. T. H. and son, very ingenious dyers of *printed* velverets, fustians, &c. near Manchester, some time since informed me of their having purchased the knowledge of an advantageous method of using the bark for this particular kind of dying, and of their having practised it with so much success as to have wholly laid aside the use of weld. This method they afterwards gave me an account of, in consequence of my offering to repay what it had cost them; which I did from a desire to afford the public all possible information on this subject. Their account is as follows, *viz.*

“ In using the Quercitron bark, for every four pieces of half-ell velverets, about forty yards long, we take eight pounds of the light coloured bark and put it into a cask large enough to hold about 70 gallons, open at the top, and provided with a spigot and faucet placed about six inches from the bottom to draw off the liquor: we fill this cask with boiling water, stir it well, and let it remain upon the bark for three hours or more; and then after the (*printed*) goods have been well washed out of the dying liquor, for the four pieces we put four pounds of Malaga sumach into a copper nearly filled with water, and with a very little fire under it; in this we put and keep the goods for about one hour, during which

which the dove or drab colours may be rendered sufficiently dark by keeping the liquor, at most, a little more than blood warm. When the goods are taken out of the sumach liquor, they must be rinsed in water; and whilst this is doing, we draw the clear bark liquor out of the cask and put it into a copper with as much water as will serve to dye the goods conveniently; we then light a fire and gradually bring the liquor to a blood warmth in about an hour, keeping the goods therein till the yellow becomes sufficiently dark or full, and taking care that the liquor be not made too hot. The goods, being well washed after dying in this way, will be found white without branning."

It ought to be remembered, that, according to this method, the sumach is to be applied separately *before the bark*, instead of being applied *after or along with it*, as I have just recommended in callico printing. How far this method may be preferable to the other for the dying of printed velverets, future experience must determine; though certainly that of Messrs. H. and son ought, on this point, to have great weight even at present. In callico printing, however, this method of applying the sumach and bark has been tried, not only by the experiments which I have made upon a small scale, but by those which an ingenious callico printer made sometime since on a larger one; at my desire, and in both, without affording any reason to prefer it over the other.

It can hardly be necessary for me to mention here, that the Quercitron yellow produces a green upon

upon an indigo blue, and an orange upon the madder red, in the same ways and by the same means which enable the weld to produce these colours in callico printing. Nor need I mention the advantage which the bark possesses over weld in this way, by not tarnishing the madder colours upon pieces where such colours have been previously dyed; this advantage being now generally known and acknowledged.

Of the Uses of Quercitron Bark, in producing Topical Yellow and other Colours, profubstantively, upon Cotton and Linen.

By the denomination of *profubstantive* topical colours, I mean certain mixtures, in which the colouring matter and the mordant or basis are combined in a fluid state, fit to be applied together by the pencil, block, &c. to linen or cotton, as explained at page 176 of this volume: these are what callico printers have usually named *chymical colours*; an appellation too vague to be retained in a work which aims at precision and systematical arrangement.

Were it possible to obtain a sufficient number of *lasting* and *bright* colours of this kind at a moderate expence, the art of callico printing would soon reach the highest degree of perfection. Whether so many of these ever will be discovered, as to render topical dying unnecessary, I know not; but if we cannot obtain all that is desirable in this respect, the art will at least derive benefit from any improvement in the few profub-

substantive topical colours now in use; and more especially from any addition to their number.

My readers already know that alumine or the earth of alum when dissolved, especially in the acetous acid, and conveyed into the pores of linen or cotton, is able afterwards to attract to itself different adjective colouring matters, applied either by general or by topical dying, so as to produce lasting red, yellow, and other colours; and it is much to be regretted that for reasons which I have endeavoured to explain in other parts of this volume, the same mordant will not produce colours equally permanent, when it has been previously mixed with the colouring matter, and is afterwards applied (with it) topically to linen or cotton. The difference in this respect is indeed very great among the madder colours; those dyed upon an aluminous basis, applied separately, being always very durable, whilst those given by profubstantive topical application fade and decay very speedily. The difference is however so much less when colours are produced in these different ways from Quercitron bark instead of madder, that I can with confidence recommend the bark as affording better and more durable profubstantive yellows for topical application, than any thing else yet discovered. The most simple yellow of this kind which I have to offer, may be prepared in the following way and proportions, *viz.* For three gallons of profubstantive tingent liquor, let three pounds of alum and three ounces of clean chalk be first dissolved in a gallon of hot water, and then add two pounds of sugar of lead; stir this mixture occasionally during the space of twenty-four or thirty-six hours,

then let it remain twelve hours at rest, and afterwards decant and preserve the clear liquor; this being done, pour so much more warm water upon the remaining sediment, as, after stirring and leaving the mixture to settle, will afford clear liquor enough to make, when mixed with the former, three quarts of this aluminous mordant or acetite of alumine. Then take not less than six, nor more than eight, pounds of Quercitron bark properly ground, put this into a tinned copper vessel, with four or five gallons of clean soft water, and make it boil for the space of one hour at least, adding a little more water if at any time the quantity of liquor should not be sufficient to cover the surface of the bark: the liquor having boiled sufficiently should be taken from the fire, and left undisturbed for half-an-hour, and then the clear decoction should be poured off through a fine sieve or canvass strainer. This being done, let six quarts more of clear water be poured upon the same bark, and made to boil ten or fifteen minutes, both having been first well stirred; and being afterwards left a sufficient time to settle, the clear decoction may then be strained off, and put with the former into a shallow wide vessel to be evaporated by boiling, until what remains, being joined to the three quarts of aluminous mordant before mentioned, and to a sufficient quantity of gum or paste for thickening, will barely suffice to make three gallons of liquor in the whole. It will be proper however not to add the aluminous mordant until the decoction is so far cooled, as to be but little more than blood warm, and these being thoroughly mixed by stirring, may afterwards be thickened by the gum of Senegal or by gum arabic, if
the

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the mixture is intended for penciling; or by a paste made with starch or flour, if it be intended for printing.

Where gum is employed, it will be proper first to dissolve it in water, using only what is barely sufficient to produce a solution, lest a greater quantity of water should increase the mixture beyond the quantity of three gallons, for which the portions of bark and aluminous mordant here prescribed will properly suffice, but not for more, without weakening the colour in some degree; and for this reason it may be safest to evaporate the decoction rather more than seems necessary; because, when mixed with the other ingredients, if the whole proves to be less than three gallons, the deficiency may be readily supplied by a little warm water.

In preparing this mixture however, great care must be taken to thicken it only so much as may be necessary to keep it from running or spreading beyond the proper limits; since every degree of thickening, beyond this point, will hinder the colouring matter from penetrating sufficiently into the fibres of the linen or cotton, and thereby render the colour superficial and feeble.

When this profubstantive mixture (which I shall distinguish as No. 1.), after being duly prepared, has been applied to linen or cotton by the pencil or otherwise, the pieces should be thoroughly dried by a stove heat, and afterwards placed in clean running water, to remove the superfluous colour; and if running water be wanting,

ing, other suitable means are to be employed for this purpose.

A good lively yellow may be produced in this way, not indeed quite so lasting as that obtained when the mordant alone is applied first, and the colouring matter afterwards, by topical dying: it will however be able to bear the action of sun and air, and also of soap in washing, for so long a time, as almost to deserve the appellation of a *fast* colour.

It must, however, be observed that this yellow, though nearly or quite as high as that given by topical dying with either weld or Quercitron bark, does not prove so high and full as is desirable for this mode of application; since colours which are applied by the pencil bear but a small proportion to the others with which they are intermixed, and are therefore required to be more strikingly full that they may not be overlooked; and it is only in this respect that the colour obtained from French berries, and called the *berry* yellow, has given any degree of satisfaction, it being of all others the most fugitive and fallacious. To relieve callico printers from all temptation to use a colour which, being fitted only to deceive, ought never to have been used, I have made numberless trials with the Quercitron bark, joined to almost every possible mordant or basis; and of these some have been attended with success, though the means employed in several of them are either too expensive or too difficult of application for general use, by persons not versed in chymical operations. There are others however not liable to these objections; and

and perhaps all things considered the most convenient, among the several means of raising the Quercitron yellow, for profubstantive topical application, and at the same time of increasing its durability, may be found in the nitrate of copper, and the nitrate of lime, added to the mixture No. 1. just described. It is indeed true, that some of the solutions of tin produce still higher yellows with the Quercitron bark; but they are liable to at least two objections, which will be particularly mentioned hereafter.

If copper in small pieces be put by a little at a time into a large open glass vessel, partly filled with single aqua fortis, until the acid can dissolve no more of the metal; and if the solution be left open to a free access of air, it will soon be wholly converted into blue chrystals, which are what I mean at present by the denomination of nitrate of copper. About one pound and a quarter of this salt may be added to the three gallons of profubstantive yellow No. 1. together with four ounces of pure unslacked lime, previously mixed with eight ounces of single aqua fortis. Clean oyster-shells thoroughly burnt will afford the best lime for this purpose; which should be beaten into powder before it is put into the aqua fortis, to form the nitrate of lime here wanted. This, as well as the nitrate of copper, should be added to the decoction of bark before mentioned soon after the aluminous mordant, and before the liquor has been thickened by gum or paste; and the mixture should afterwards be well stirred, and kept a little more than blood warm for half an hour before the thickening is added.

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The nitrates of copper and of lime, joined in this way to the mixture No. 1. will considerably raise the yellow colour, and also enable it, for a longer time, to withstand the action of sun and air; they will also enable the colour to bear the action of vinegar and weak acids, a little better than it otherwise would, though I do not consider this last as any test, of the goodness of a colour, nor as being a circumstance of any great importance. This profubstantive colour, I shall distinguish as No. 2. And considering that the bark in this way affords a colour full as high, and infinitely more lasting, as well as cheaper, than any which can be obtained from French berries, I think those callico printers, if there should be any, who may hereafter continue to employ the latter, will shew themselves strangely unmindful of their own interest, as well as of their duty to the public, and the credit of their art.

The nitrate of alumine, employed as a mordant with the decoction of bark, produces a profubstantive topical yellow of considerable durability; but it is apt to acquire too much of a brownish complexion.

The muriate of alumine, mixed with the decoction of bark, produces in this way, effects very similar to those of common alum; and this is also the case where a tartrate of alumine is employed. Alumine dissolved in the pyro ligneous acid, being tried with the bark in this way, produced effects perhaps a little, though but a very little better.

None

None of the solutions of alumine by pot-ash, soda, or ammoniac, succeeded as mordants with the bark, for topical application, so well as the solutions made by acids.

If a decoction be made from six or eight pounds of bark, as directed for the preparation No. 1., but without any of the aluminous mordant, and if two pounds of the nitrate of copper, lately described, be dissolved therein whilst a little warm, and the mixture afterwards properly thickened, it will produce, when applied to linen or cotton, a good profubstantive *yellowish green*, capable of bearing exposure to sun and air, and washing with soap, so as almost to deserve the name of a fast colour. By adding four ounces of lime, mixed with eight ounces of aqua fortis, the colour will be improved; and it may be rendered still more beautiful, and I think a little more lasting, by adding immediately after the nitrate of copper, one pound of ammoniate of copper, made by pouring a pound of the aqua-ammoniac of the New London Dispensatory into a close glass vessel, with a sufficient quantity of filings, or small bits of copper, and keeping the vessel closely stopped until the alkali has combined with as much copper as it can dissolve, and thus acquired a very beautiful deep blue colour. This yellowish green profubstantive mixture I shall distinguish as No. 3.; and I believe there are no other means by which a similar colour can be obtained of equal beauty and durability.

The ammoniate of copper alone produces, with the decoction of bark in this way, a greenish yellow deserving of notice.

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The acetate of copper (verdigrise dissolved by vinegar) mixed with a decoction of the bark, and topically applied upon cotton, produces a full brownish yellow, which however proves not so lasting as either No. 1. or No. 2.

And the muriate of copper, with the decoction of bark, produces in this way a yellowish olive, which soon fades upon linen and cotton.

It has already been noticed, that cottons impregnated with the oxyds or solutions of tin as a basis of colour, and then dyed with Quercitron bark, imbibed colours highly beautiful, and capable of resisting the action of boiling soap suds as well as of strong acids; but at the same time highly fugitive, when exposed to the sun and open air, a defect which it would have been reasonable to expect even in a greater degree, where the tin basis, instead of being previously fixed in the cotton, was first united to the colouring matter, and afterwards applied therewith profubstantively. A contrary effect however really takes place in some degree.

If a decoction be made from six pounds of bark, as for the preparation No. 1. (but without any aluminous mordant,) and one pound, or one pound and a quarter of the murio-sulphate of tin, so often mentioned, be added, the mixture being afterwards well stirred and properly thickened, will afford a very bright and full profubstantive yellow, liable indeed to become a little brown by exposure to the sun and air; but at the same time of considerable durability, and able to withstand the action of acids or boiling soap

soap suds. It must however be remembered, that the oxyd of tin has a stronger attraction than that of iron, for most vegetable colouring matters, and especially for that of madder; and therefore when prosubstantive colouring mixtures, containing solutions of tin like that just mentioned, are applied *closely* upon madder purples or blacks, (made such by the oxyd of iron,) these latter colours will become red where-ever they are touched by these mixtures. And for this reason, whenever a prosubstantive yellow is wanted to be laid immediately upon the edge of a dark madder colour, (which is most frequently the case,) it will be proper to employ the preparation, No. 2.

The nitro-muriate of tin, made with about two parts of nitric to one of muriatic acid, produces in this way, with the decoction of bark, a very high lively yellow, capable of resisting strong acids, boiling soap, &c. but very liable to become brown by exposure to the sun and air; an effect which I found lemon juice had the power of preventing, in spots which, for another purpose, had been wetted therewith. Olive oil applied so as to cover yellow spots or figures produced by the decoction of bark and nitro-muriate of tin, appeared to have no effect in defending or preserving the colour from injury by exposure to the sun and air; and linseed oil applied in the same way did manifest harm, the spots covered by it having acquired a blackish hue after a few weeks exposure to the weather. These joined to other facts will hereafter help us to some useful conclusions. Muriate of tin with the decoction of bark, applied prosubstantively

stantively to cotton, affords a very lively delicate yellow; but it is less capable than the former of resisting the action of soap, and of acids; nor does it long bear exposure to sun and air. This is also true of the yellow produced in this way by the tartrate of tin and decoction of bark.

The sulphate of tin mixed with a decoction of the bark, and applied in this way to cotton, gives a kind of cinnamon colour, sufficiently lasting. Phosphate of tin produced only a dull brownish yellow with the decoction of bark. Tin dissolved by cream of tartar, mixed with twice its weight of muriatic acid, produced, with a decoction of the bark, profubstantively upon cotton, a very lively strong yellow, of considerable durability. I have tried many other solutions and combinations of tin with the bark, and indeed almost every one which it is possible to form, but without any effects better than those which may be obtained from the mixtures already mentioned. My readers therefore will not require a particular account of them, especially as the use of all profubstantive yellows which contain solutions of tin, though they afford by much the highest and most beautiful colours, must prove very limited by reason of their effect of reddening the dark madder colours.

It has been already observed, that the decoction of bark with the nitrates of copper and lime, and the ammoniate of copper, produces a good profubstantive yellowish green; and this may be rendered darker and fuller by superadding a portion of the logwood blue. Two callico printers have assured me that by combining

the bark and logwood with particular solutions or preparations of copper, they had been able to obtain a green for topical application so fast, as to bear the process of field bleaching without injury; and one of them declared, that it was by adding to a decoction of bark and logwood boiled together, a suitable portion of sulphate of copper and of verdigrise, with a little pot-ash; this last, and the effervescence which it produced, he seemed to think of importance. As yet, however, my endeavours to produce a green fully answering this description have not succeeded, though they have several times been attended with such appearances of success, as will induce me to make farther trials. Those hitherto made seemed to have failed principally by the want of sufficient permanency in the blue or logwood part of the green colour. A great number of experiments, made at least seventeen years ago, taught me, that a beautiful profubstantive blue, capable of resisting sun and air for a considerable time, when applied topically upon linen or cotton, might be obtained by combining the colouring matter of logwood with the sulphate of copper and the ammoniate of copper.

Six pounds of logwood boiled with water, as directed for the Quercitron bark, will afford colouring matter enough for three gallons of liquor when thickened; to this decoction whilst warm, and before it is thickened, two pounds of blue vitriol may be added, and as soon as it is dissolved, two pounds of ammoniate of copper, made as already explained; and the liquor after being well stirred may be thickened and applied as usual. By substituting the nitrate of copper

for the sulphate of that metal, a dark blue may be produced, equally durable but not so lively and beautiful; though I think this last rather preferable to the other, for the purpose of forming a profubstantive green with the Quercitron yellow; for which purpose it will be sufficient to mix as much of this logwood blue with the yellowish green, No. 3, as may serve to produce the particular shade of colour wanted; or the logwood blue may be added to the yellow, No. 2, for the like purpose. And though the greens produced in these ways are not so lasting as to deserve to be called fast colours, they are as good as any which I have yet been able to produce by uniting the Quercitron and logwood colouring matters, and indeed are such as it may be often convenient to employ.

If a suitable portion of strong iron liquor be mixed with a decoction of the Quercitron bark made as already directed, and the mixture be properly thickened, a profubstantive drab colour of some durability for topical application, may be produced; and this mixed with an equal portion of the preparations No. 1 or No. 2, will produce an olive. If a solution of iron, by a diluted muriatic acid, or by a diluted nitric acid, be employed for this purpose instead of iron liquor, it will produce colours a little more lasting; but these solutions should be employed sparingly, that they may not hurt the texture of the linen or cotton to which they are intended to be applied.

Zinc, dissolved by the sulphuric, the nitric, and the muriatic acids, separately, and mixed with

with the decoction of bark, produces brownish yellow colours of different shades, but none of them sufficiently lasting when topically applied upon linen or cotton.

Mercury, dissolved by the different acids, produced with the decoctions of the bark different brown and yellowish brown colours, but none of them more durable in this way, than those afforded by different solutions of zinc.

The nitro-muriate of Platina, mixed with a suitable portion of decoction of bark, and topically applied either to linen or cotton, produces strong full-bodied snuff colours, which bear the action of acids and of the sun and air.

The nitrate of silver, mixed with a decoction of the bark, produces by topical application upon linen or cotton, strong dark brown and cinnamon colours of considerable durability.

The nitrate of lead, with the colouring matter of bark, produces in this way a drab colour of equal durability.

The nitrate of bismuth, with a decoction of the bark, produces a very full and strong brownish yellow, which would prove lasting, were it not liable to become almost black by alkaline sulphures, by sulphurated hydrogenous gas, and sometimes by the action even of common soap.

The muriate of bismuth produces a drab colour with the bark, and the sulphate of that
D d 2 metal

metal a yellow; but neither of these are lasting upon linen or cotton.

The nitro-muriate of antimony produces with the bark, a kind of snuff colour of some durability on linen and cotton; and different shades of brown were produced in this way by the nitrate and the muriate of cobalt with the bark, which however soon faded by exposure to sun and air.

In giving this account of the properties and uses of Quercitron bark, I have had before me notes of several thousands of experiments made therewith, in almost all possible ways, and with almost all possible chymical agents. But as a detail of their effects would more than exhaust the patience of any reader, I shall content myself with stating as I have here done, the results of those which seem most likely to prove useful; and probably what I have already stated is more than enough on this subject. I have however thought it incumbent on me to omit nothing in any degree likely to afford useful information respecting a *new dying drug*, first brought into use by my exertions, and which without them would probably have remained unknown as a dying drug for ages to come:—a drug which has already produced important benefits, especially to the art of callico-printing in Great Britain; and is likely hereafter to benefit other European nations, as well as the United States of America, in an eminent degree. The consumption has indeed hitherto been small, compared to the probable future increase; but it has been large considering

considering the short time since its properties were first made known, and the immense difficulties which attend the introduction of all new dying drugs: it appearing by the act of the 13th and 14th of Charles II. ch. 2., that nearly one hundred years had elapsed before "the ingenious industry of modern times had taught the dyers of England the art of fixing the colours made of logwood." And though indigo, the most valuable of all dying drugs, had been known in Asia for at least two thousand years, the use of it was either prohibited or restrained for a considerable time in different European countries, from an erroneous belief that its colour was fugitive: so difficult has it always been found to bring dying drugs into their *due estimation*. But though the Quercitron bark has been employed only for so short a time, I flatter myself that the account which I now offer of its properties and uses, will prove much more complete than any yet given of the properties and uses of any other dying drug, even among those which have been known for many ages.

C H A P. XIII.

Of the Properties and Uses of Juglans Alba, or American Hicory; of the Weld Plant, Fustic, and other Vegetables, affording yellow adjective Colouring Matters.

“ La couleur jaune est celle que la nature a repandue partout avec la plus grande profusion,—elle peut etre regardée de droit comme couleur primitive.”

Annales de Chymic. tom. xvii.

ARTICLE 1st. *American hicory*:—Not only the bark but the green leaves and the rinds of the nuts of this tree, yield an adjective colouring matter so very similar to that of the Quercitron bark, that all the instructions which I have given respecting the latter, will be found applicable to the hicory; allowing only for the difference between their respective proportions of colouring matter; that of the hicory bark being about one-third less than what is contained in a like quantity of Quercitron bark. It is this difference, joined to the greater difficulty and expence of grinding the hicory bark, on account of its great hardness and toughness, which has enabled the Quercitron bark almost wholly to supersede the use of the hicory; for, excepting the profubstantive topical yellows, for which it does not seem to answer quite so well, there is perhaps no purpose to which the colouring matter of the hicory may not be applied with effects as good as those resulting from the
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Quercitron bark; and I have sometimes thought, that some of the *varieties* of this tree might be preferable to the Quercitron bark, for imitating the greenish lemon yellow of the weld plant on wool, with an aluminous basis. I say of some of the *varities*, because there certainly are considerable differences between the shades of yellow produced by the several varieties of the hiccory tree; that for instance which Marshall calls *juglans alba acuminata*, produces a clear lemon yellow, whilst the *juglans alba minima* produces a fuller, though not a very bright, yellow; and the *juglans alba odorata* a yellow, which is very full and also very lively.

Generally however the hiccory bark employed in the way of callico printing, or topical dying upon linen and cotton, produces colours very similar to those of the Quercitron bark, both upon the aluminous and ferruginous bases, and with no greater degree of stain or discolouration upon the parts intended to be kept white. This also is one of the vegetable colouring matters, of which the use has been exclusively secured to me for a term of years by an act of parliament.

Art. 2. The *weld plant* (*reseda luteola* Lin.) grows wild, as well as by cultivation, in many parts of Europe; the cultivated plants are however smaller than the wild, and more abundant in colouring matter. There are some varieties of this species; two or three years since a little parcel was put into my hands, which had been brought from Hamburgh, and of which the stalks were not more than a fourth part so high or so large as those of the weld raised in this kingdom.

dom. I did not however find much superiority in the quality of its colouring matter, though in quantity it yielded at least four times as much as an equal weight of either English or French weld; and the price, as I understood, was proportionably greater. This variety of the weld, according to my information, grows and is made use of in several parts of Germany. I have already noticed all the particulars of any importance in which the colouring matter of weld differs from that of the Quercitron bark, and have therefore but little to add respecting the former; both affording adjective colours of the same shades by the same basis or mordants, with only a few exceptions, of which the greatest part have been already mentioned in treating of the bark.

Weld requires the growth of nearly two summers before it comes to maturity; and the crop is besides liable to fail from so many causes, that it cannot be a desirable object of agriculture, especially in Great Britain. It moreover occupies nearly one hundred times more space than a quantity of bark, capable of yielding an equal portion of colouring matter, and of dying an equal weight of cloth; a circumstance which compels the dyer and callico-printer to extract the colouring matter by previous boiling; since if the weld were put into the dying vessel, as is done with the bark, there would be no room for any thing else. It also renders the transportation into Scotland and the northern counties of England, (where it will not grow,) so expensive, that the callico-printers of Lancashire, Carlisle, Glasgow, &c. could not have exercised their art,

either

either so advantageously or so extensively as they have done for some years past, had not the Quercitron bark enabled them almost wholly to lay aside the use of weld.

That the colouring matter of weld may be more readily extracted; the woollen-dyers frequently add a little stale urine, or lime and pot-ash to the water in which it is boiled: and in preparing wool or cloth, by impregnating it with the aluminous basis, they commonly employ three or four ounces of alum and one of tartar, for each pound of the woollen cloth. Tartar is supposed to render the yellow colour a little more clear and lively. I have good reason however to believe, that it may, without inconvenience, be wholly omitted in dying with weld, as well as with the bark, excepting only for those delicately bright and greenish shades, for which it is now usual to employ a portion of the nitro-muriate of tin (dyers spirits) along with alum in boiling or preparing the wool and cloth; and for which the use of tartar will prove highly beneficial.

In topical dying or callico printing, very little less than the heat of boiling water will suffice to fix the colouring matter of weld, and the parts wanted to be kept white, are then so much stained by it, and this stain is so difficult to remove, that during the damp cloudy weather which generally prevails in winter, four or five weeks exposure on the grass will hardly prove sufficient for that purpose. This is a serious inconvenience which does not attend the use of the bark.

Weld

Weld also produces another bad effect when employed for topical dying upon linens or cottons, which have previously received a course of madder colours; for in this case the *weld yellow* by a particular affinity applies and fixes itself upon these colours so copiously as to change their appearance, and tarnish their lustre greatly; and this is another defect from which the bark is nearly, if not wholly, exempt.

By the act of the thirteenth of his present Majesty, ch. 77, the sum of 2000l. was granted to Dr. Richard Williams as a reward for his invention of a fast green and yellow dye on cotton, yarn, and thread. This supposed fast dye was given with weld by the help of a mordant; the composition of which (that foreigners might not enjoy the benefit of it) Dr. Williams was permitted to conceal, and to supply the cotton and thread dyers therewith at a certain price. I have however reason to believe, that it was either a solution of tin alone, or of tin and bismuth, which enabled the weld yellow, as it enables that of the bark, to bear the action of acids and of boiling soap-suds, though unable to bear the action of sun and air. This defect, however, was not readily discoverable by the method which Dr. Williams employed to obtain a favourable testimony from the dyers on this subject. His method was that of weaving the dyed yarn into pocket handkerchiefs, and giving them to be worn in the pockets of those who were afterwards to attest the goodness of his dye; and as handkerchiefs inclosed in a pocket are not exposed to the sun and air, the defect in question was not perceived until some time after

after the reward had been paid for a supposed invention of no value, and of which, I believe, no use is now made.

Art. 3d. *Rhus cotinus* Lin. or venice sumach, improperly called *young fustic*, is a shrub growing principally in Italy, and the South of France; whence the root, as well as the stem or trunk of the shrub, deprived of the bark, are brought and employed (chipped) for dying a full high yellow, approaching to the orange, upon wool or cloth prepared with the nitro-muriate of tin, or dyers spirit. But the colour obtained by these means always proves extremely fugitive; and it is besides neither so bright nor so high as the yellow which may be more cheaply obtained from the Quercitron bark, and the muriate or nitro-muriate of tin, with alum. Four pounds of the *rhus cotinus* chipped, afford no more colour than one pound of the Quercitron bark.

Art. 4th. *Morus tinctoria* Lin. or fustic, called improperly *Old Fustic* by the English, and Bois Jaune by the French, is a large tree growing naturally in Jamaica, Porto Rico, Tobago, and almost all the other West-India islands; its wood is of the colour of sulphur, and has within little more than a century, been brought into general use as a dying drug, though the yellow colour which it affords with an aluminous basis is neither high nor bright; it has however the advantage of being durable, and of not being thrown down or made latent by acids so much as the weld and Quercitron yellows; and for this reason it is now very commonly employed
(chipped)

(chipped or ground) in dying Saxon greens upon cloth, with the sulphate of indigo, as mentioned at pages 337 and 338; the muddiness of its yellow being of but little detriment to the full dark greens most frequently dyed with it in this way.

It is also very much employed for dying drab colours upon cloth, and especially on cotton-velvets, fustians, &c. with an iron basis, and olives with a mixture of this and of the aluminous basis, as has been mentioned in the preceding chapter, where so much is said respecting the means and modes of employing the bark, which may be applied with equal advantage to the wood in question, that I shall add but little more upon this subject. Four pounds of this wood chipped, yield about as much colouring matter as one pound of the Quercitron bark; and allowing for this difference of quantity, it may be employed for general dying with the several mordants or bases proposed for the bark; remembering always that the yellow colour which it affords, can never be made to acquire any thing like an equal degree of clearness and brightness with that of the bark or of the weld; and for this, with some other reasons, it is not likely to be ever employed in callico printing.

I am not yet able to ascertain whence the word fustic was derived to our language. Venice sumach appears to have been long distinguished in France by the name of *Fusset*, and I suspect that our dyers with the wood introduced the name, and changed it to *Fustic*; such changes
having

having frequently happened in other cases. The *morus tinctoria* being afterwards brought from America, and also employed for dying yellow, and being destitute of a name, appears to have likewise acquired that of fustic; and a confusion having arisen by thus giving the same name to two different species of wood, a distinction was improperly created by calling that of the Venice sumach, *Young Fustic*, (as being manifestly the wood of a small shrub,) and that of the *morus tinctoria*, (which is always imported in the form of large logs or blocks) *Old Fustic*. At what time these epithets were first applied, to create this distinction, I have not discovered; but they must have been in general use, at least 130 years ago; because Sir William Petty, in an account "of the Common Practices of Dying," which he gave to the Royal Society when first instituted, mentions Venice sumach under the name of "*Young Fustic*," and the *morus tinctoria* under that of "*Old*," as being their common and appropriated names. In this way, however, many persons have been misled so far as to conclude that two very distinct dying drugs (the one a small *European shrub* of the sumach kind, and the other a large *American tree* of the mulberry kind) were the same, or differing from each other only in *point of age*. The French have indeed avoided this source of error, by leaving the Venice sumach to bear exclusively the name of *Fustet*, and giving that of Bois Jaune or yellow wood to the *Morus Tinctoria*; and perhaps it might be well for us even now to call the latter *yellow wood*, or *dyers mulberry*, in order to avoid the error in question, were it not that what is called young fustic

fustic is likely soon to fall into such absolute disuse as to render any change unnecessary. The wood known in England by the name of green ebony, possesses a species of yellow colouring matter very similar to that of the *morus tinctoria* in dying, and is sometimes employed in its stead.

Art. 5th. The common sumach of Spain, Portugal, and other parts of Europe (*rhus coriaria* Lin.) affords a yellow dye with the aluminous basis; but so pale and of so little brightness, that it is very rarely employed for the purpose of giving a yellow colour only; it however possesses another species of colouring matter similar in most respects to that contained in galls, and therefore capable of dying black with iron and the solutions of that metal: this species of colouring matter, and the application thereof, upon wool and cotton, will be treated of in their proper place. The principal uses of sumach in callico printing have been already noticed in the preceding chapter. Used by itself in this way, it stains the white parts very durably; but used with the *Quercitron* bark it is thereby hindered from giving any stain, and at the same time it obviates that which the bark might otherwise communicate.

Art. 6th. The unripe berries of the *rhamnus infectorius* of Linnæus, are called French berries, and chiefly employed for preparing a lively but very fugitive yellow for topical application in callico printing. Cotton printed with the aluminous mordant, and dyed with these berries, instead of weld or *Quercitron* bark, receives

receives a full bright yellow; but in this and every other way it fades so speedily, that the use thereof is a gross imposition, which the public ought not to tolerate, whilst there are other means of giving such durable yellows as will not deceive or disappoint the wearers. There is a particular species or variety of the *rhamnus infectorius* growing in Candia and other parts of the Levant, yielding berries larger than those brought from the south of France; they are distinguished by the name of Turkey berries, and preferred to the French, though the colours of both are equally fugitive.

Art. 7th. Saw-wort, *serratula tinctoria* Lin. affords a good substitute for weld in dying upon the aluminous basis, with which it communicates a bright lemon yellow of considerable durability. The common preparation with alum and tartar, is to be employed for wool and cloth; or if a brighter colour be wanted, the preparation may be given with nitro-muriate of tin, (dyers spirit,) and half as much tartar.

For giving a very inferior yellow upon coarser woollens, the dyers broom (*genista tinctoria* Lin.) is sometimes employed, with the common preparation of alum and tartar.

All the five species of *erica* or heath growing on this island, are, I believe, capable of affording yellows much like those obtained from the dyers broom—their colours may indeed be raised and brightened by the solutions of tin, but when this has been done, I have always seen them prove fugitive. This I have also found

to be the case of the yellow dyed with the bark and shoots of the Lombardy poplar, *populus pyramidalis*, recommended by Mons. d'Ambourney. He states the expence of *materials* for preparing and dying sixty pounds of wool with the young shoots of Lombardy poplar, and the tin basis, to be eighteen livres, which is more than double what it would cost to produce a much better colour with the Quercitron bark, as I have already mentioned in the proper place.

According to Scheffer and Bergman, the leaves of the sweet willow, (*salix pentandria*), gathered about the end of August or beginning of September, and dried in the shade, afford, if boiled with about 1-30th of pot-ash, a fine yellow colour to wool, silk, and thread, impregnated with the aluminous basis. I have, however, made no trial with them as yet.

Art. 8th. The American golden rod, *solidago canadensis* Lin. affords very beautiful yellows to wool, silk, and cotton upon the aluminous basis. Hellot seems to have been the first who attempted, though without success, to introduce this plant into general use as a yellow dying drug; and Messrs. Gaad and Succow have since made the like attempts with no better success; though I can affirm from the results of many trials, that it would prove a very advantageous substitute for the weld in callico printing; the colour which it affords in this way, to parts printed with the aluminous mordant, proves highly beautiful, and the stain or discolouration produced upon the unprinted parts,

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is much less considerable and much more easily discharged than that of weld. The plant (golden rod) is also more rich in colour, and capable of being raised with great ease. It grows naturally in abundance, almost every where, between Carolina and Hudson's Bay.

Kalm says, that the three-leaved Hellebore, (*helleborus trifolius*), called Tiffavoyanne jaune by the French in Canada, is there used by the Indians in giving a fine yellow colour to several kinds of work, which they make of prepared skins; and that the French having learned this from them, dye wool and other things yellow with this plant. Besides these there are many other vegetables capable of affording adjective yellow colours, both with the aluminous basis and that of tin, particularly the seeds of purple trefoil, lucerne, and fenugreek, the flowers of French marygold, the chamomile, (*anthemis tinctoria*), the ash, (*fraxinus excelsor*), the fumitory, (*fumaria officinalis*), with several others which need not be named, as not being likely ever to come into use. There is indeed so much difficulty in always producing the exact shades of colour which dyers are required to imitate, that the use of *various* materials for obtaining *similar* effects must prove highly inconvenient. A few drugs occupying but little space, rich in colouring matters, and capable of being always obtained as well as extensively applied, by saddening and otherwise varying their respective colours, are what the dyers most need: by being constantly occupied with a few such drugs, they acquire that degree of dexterity and certainty in

using them, which alone can prevent disappointment in the nice operations of this art.—
Such a drug is the Quercitron bark.

Having thus noticed, as far as seemed expedient, the different adjective yellows, I shall in my next volume proceed first to the reds, and afterwards to the other remaining adjective colours.

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A P P E N D I X.

WHAT I have mentioned respecting indigo in the former part of this volume, was printed in the beginning of the year 1791. I did not at that time know of an account, which Dr. Roxburgh had then very lately addressed to the Court of Directors of the East-India Company, of a new species of nerium, (rose bay,) and of a process for manufacturing indigo from its leaves, which has since been published in Mr. Dalrymple's Oriental Repertory.

Subsequent to the time when that account was written, so many facts, the result of numerous experiments and much inquiry, came to the knowledge of Dr. Roxburgh respecting the tree, the process for preparing the indigo, its quality, &c. that he thought a more complete description thereof to be necessary, especially as the incomparable beauty and superior excellence of the indigo so obtained, appeared to render it an object highly interesting; and as there were already some plantations of the nerium in great forwardness in Bengal, raised from seeds which he had sent thither in the years 1790 and 1791, from the Rajamundry Circar. Such a description was accordingly prepared by Dr.

Roxburgh, with the addition of “ a *second* part,
 “ containing a brief account of the result of
 “ various experiments made with a view to
 “ throw some light on the theory of that beau-
 “ tiful production (indigo); with an appendix
 “ containing a botanical description, &c. of a
 “ *second* new indigo plant; the whole illustrated
 “ with necessary drawings, and addressed to the
 “ Hon. Sir Charles Oakly, Governor and Pre-
 “ sident in Council, &c. at Fort St. George,
 “ to be transmitted to the Honourable Court of
 “ Directors of the United East India Company,
 “ and committed to their protection, with a
 “ view to encourage a more extensive cultiva-
 “ tion of those plants which yield the best
 “ indigo, and to improve the manufacture
 “ thereof.”

The papers containing these descriptions and accounts having been put into my hands at the India House, and reason having been given me to believe that, by publishing their contents, I might promote the views as well of the author as of the Court of Directors, I have made, and shall here subjoin an abstract of the more interesting parts thereof.

Dr. Roxburgh observes, that St. Helena and the West-India Islands, contain a great abundance of soil just suited to the *nerium tinctorium*, i. e. hills and the lower regions of mountains where little else is found than rocks, stones, and barren waste lands, such being the soil and situation in which he has always found it growing in India. “ One of the circumstances, says Dr. Roxburgh, that have lately come to my knowledge

knowledge respecting this tree is, that the natives of the Vizagapatam and Ganjam districts, and of some parts of the Carnatic, are acquainted with the property of its leaves: Dr. Patrick Ruffel writes me from England, that amongst the papers of a most worthy sensible man, an old college companion of my own, the late Mr. George Campbell, (who was Surgeon on this establishment, and died of wounds he received in the action between Col. Bailey and Hyder Ally in 1780,) there was found an account of the tree, and of the fact that the natives made indigo from its leaves, which was wholly unknown to me when I first wrote on the subject."

Dr. Roxburgh describes the *nerium tinctorium*, or thit ancalloo of the Hindoos, as a tree of the middle size, agreeing perfectly in its botanical characters with the *nerium* of the Linnæan Sexual system, and from the quality of its leaves, says he, "I have called it *nerium tinctorium*, dyers rose bay; for to me it seems a new species, approaching nearest to the *nerium antidysentericum*, which yields the conessi bark of our materia medica: they are both natives of the lower regions of those mountains which bound the Rajamundry Circar on the north-side, and are so much alike, the *nectarium* excepted, that without a tolerable knowledge of both, the one may be mistaken for the other. The trunk of the *nerium tinctorium* is irregular in shape, being when old from one and a half to two feet in diameter, and from eleven to fifteen feet up to the branches. The bark when old is scabrous, but when young,

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smooth,

smooth, and ash-coloured. The wood is remarkably white and close grained; in appearance resembling ivory; the leaves when full grown are from six to ten inches long, and from three to four broad; they are numerous, opposite, short petioled, oval, pointed, pretty smooth, and of an intire pale green. The nectary which is wanting in the nerium antidysentericum, has many ramous white filaments crowning the mouth of the tube of the corol.

This tree also grows plentifully throughout the Carnatic, and in every part of the Circars, where there are hills or mountains, being an extent of above 1000 miles in length. It contains a milky juice, chiefly in the tender branches and young leaves, which flows out on their being wounded. Near inhabited places, it is so often cut for fire-wood, that in such situations it is always found in the state of a very small tree or a large bush. To make it yield a large supply of the best leaves for producing indigo, it should be kept low, as is done with the mulberry plantations for feeding silk-worms, and, like them, the more it is cut down, the more will it increase; as many shoots issue from the old stumps, which in the space of one year grow to various heights from one to ten feet, according to the nature of the soil and season. The tree casts its leaves about the beginning of, or during the cold season. In March and the beginning of April, the young leaves first make their appearance, together with the flowers; by the end of April those which first unfolded, will have attained their full size; and this I have found to be the proper time for beginning to

gather the leaves for the making of Indigo; about this time also it ceases flowering, and many of the seed vessels are perfectly formed, though the seeds are not ripe until January or February. The leaves of this tree differ most essentially from those of the common indigo plant in not yielding their colour to *cold* water: I have tried every method which I could think of, and with various kinds of water, yet could never with cold water procure more than a very small proportion of a hard, black, flinty substance, which did not deserve the name of indigo; it burns very difficultly, with a white smoke, leaving dark coloured ashes; whereas that which is made with hot water burns most readily with a most beautifully deep violet-coloured smoke, and a strong peculiar smell, leaving fine white ashes; but by hot water the colour is readily extracted; for this operation however, works, very different from those by which common indigo is made, are requisite.

The most essential part of the operation consists in applying a sufficiency of heat at the least expence; for in general I have found that the price of fuel was nearly equal to every other charge. By the scalding process I have always, on a small scale, made from the common indigo plant, better indigo than I could by fermentation, and in one-fourth of the time; and what is also of great importance, without the smallest degree of the pernicious effluvia which attend the manufacture of indigo by fermentation; and moreover the twigs and leaves themselves of the indigo plant burn fiercely, after having been well dried, and will carry on the operation

without requiring any great addition of other fuel. But the works for the *nerium* have not this advantage, as the *leaves only* are scalded. In my first experiments in 1789, I used the common earthen pots of the country to scald the leaves, but for many obvious reasons large copper vessels are preferable; they may easily be made of any size, of sheathing copper rivetted together and soldered. I conceive that ten or twelve feet from the fore part, where the scupper is fixed, to the back part, are as much as one fire can act upon; and that five or six feet the other way are sufficient: the depth ought not to be more than two feet, for fear of scalding the leaves near the bottom before those near the top are done sufficiently. The agitation-vat may be built of brick or lime, as is usual for making the common fermented indigo; but it should never be more than three feet in depth. In the sequel, it will appear that the blue colour of indigo is derived from the air; it is therefore necessary to make the agitation-vat or cistern very broad, and always shallow, eighteen or twenty inches of liquor in depth being as much as ever should be allowed; the other eighteen or sixteen inches above the liquor may be called the border, and will not require to be very strong, its use being only to prevent the liquor from splashing over during the agitation. At the edge of this agitation-vat may be built a small cistern, to make and contain lime water; and it should be so built as to exclude the air, if possible, this having a bad effect on lime.

It is proper that the surface of the liquor be gently agitated by the wind, while the *fecula* is precipi-

precipitating, as it will prevent the formation of the violet or copper-coloured scum, which should not be allowed to subsist; because it hinders in a great measure the free absorption of the colouring principle, which is derived from the air of the atmosphere, (probably assisted by the contact of light,) and not from the plant itself; it being only the *base* of the commodity which the leaves yield. The place however should be free from dust. Another small cistern or receptacle for drawing off and receiving the *fæcula* (blue precipitate) is very convenient; in this it will settle at the bottom; and even then much of the mother liquor may still be drawn off by scuppers, which will render the draining, while in the bags, much less tedious. The bottom ought to slope towards the centre, where a small excavation should be made for taking up the remaining *fæcula*, and for allowing sand and other heavy impurities to settle therein. Over this small cistern the draining bags may be hung, until the liquor runs clear from them.

In the month of April the leaves begin to be fit for making indigo; and in May and June I have found them yield a better colour than in any other month. About the end of August the plant ceases to grow for the season, and the leaves acquire a yellowish rusty colour, and fall off gradually, without being succeeded by others *generally* until the next season: so that indigo can be made only during four or five months in a year with the plants which grow *spontaneously* in this part of India. The leaves of the plants raised from seed in my garden, did not yield colour till they were upwards of two years old;
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and then in a small proportion only, and of an inferior quality, compared to that of the *old* plants growing *wild*. If the leaves be picked and the best only taken, the indigo will be more beautiful than when they are taken promiscuously together with the extremities of the shoots, which will be too young, while leaves on the lowermost branches will be too old. I never could extract any thing like indigo from the tender shoots of this plant, when deprived of their leaves, though the twigs of the common indigo plants, without leaves, afford indigo readily; but of an inferior quality to that which the leaves of this plant *alone* afford. The leaves of the *nerium* give indigo not only when fresh gathered, but even when wilted and almost dried; they yield, however, the best indigo in a middle state, after being kept a day or two: when they are considerably wilted, the indigo is of a worse quality; and when dried, they afford only a dirty brown colour; though the leaves of the common indigo plant bear drying and keeping without any detriment to the indigo which they produce; and it is the practice in many parts of India to dry them before the indigo is extracted: in this respect, and in that of not yielding their colour, by cold infusion, the *nerium* leaves differ essentially from those of the *indigofera*. The *nerium* leaves collected the preceding day, are put in a copper, so as nearly to fill it without pressing, and the copper is then filled with water till within two or three inches of the top, this space being necessary on account of the expansion produced by heat. Hard spring-water is to be preferred, as contributing to increase the quantity of indigo, as well

well as to improve its quality. The fire is then lighted and kept briskly up till the liquor acquires a deep green colour, when viewed in the vessel; though if taken out and poured from one vessel into another, the stream will appear of a pale bright greenish yellow: the leaves will then begin to be of a yellowish colour, and the heat of the liquor about 150 or 160 degrees of Farenheit's thermometer; little dependance can be placed on the violet or copper coloured scum, as the leaves must be constantly moved about, and turned up and down, that they may be equally scalded. This agitation also tends to expel the fixed air, (carbonic acid gaz,) by the expulsion of which the operation is much forwarded. The fire must be withdrawn a little before the liquor affords these appearances; and all the different coppers, whose liquor is to be let into the same agitation-vat, should be ready or in equal forwardness at the same time, that the liquor may be drawn off at once. In doing this it should be passed through a hair cloth, to separate every part of the leaves from it: as soon as the whole is run off, it is to be agitated, while hot, in the common way for a few minutes, (say from five to twenty,) which will generally produce a sufficient granulation. About one 75th part of strong pure lime-water is then to be let in (the liquor being still hot) from the lime-water cistern, which requires only to be sufficiently mixed with the liquor to produce speedily a very large grain, which soon precipitates; the supernatant liquor is next to be let off, and the rest of the process continued exactly as in making the common fermented indigo.

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If the process has been properly conducted, the supernatant liquor will run off, of a clear madeira wine colour, which will prove that it retains none of the indigo. To produce one pound of indigo, between two and three *hundred* pounds weight of green leaves will be necessary, according to the season and state of the weather in which they are gathered: and at the end of August or September, I have not obtained more than half or two-thirds of the quantity which had been yielded in May and June; and even that is lessened if the weather prove wet, or if the leaves are committed to the scalding process immediately after being gathered.

This operation was performed with ease twice a-day, and indeed it might be done three times; the scalding in these large vessels requiring only about three hours, and the agitation and precipitation not more; so that as soon as the scalding of a second operation was completed, the *fecula* of the first was let out of the agitation-vat into the small square cistern, where it was suffered to remain till the *fecula* had precipitated into a still smaller bulk. The supernatant liquor was then let off by the scuppers, and the *fecula* put into bags to drain.

Mr. de Cossigny, in his Treatise on the Cultivation and Manufacture of Indigo, observes, that if the moist *fecula* be washed with warm water, in which a small quantity of vitriolic acid has been mixed, it becomes improved thereby; which is also true of the *nerium indigo*. One ounce of this acid, for as much *fecula* as will yield two or three pounds of indigo, I think sufficient

sufficient to dissolve all the extraneous matters which are mixed with the *fæcula*, and they ought to be washed away by one, two, or more subsequent washings with pure water. I have found the marine acid answer nearly as well, but not the nitrous, which rendered the indigo porous. These washings diminish the quantity of indigo remaining, but its beauty and value are greatly advanced thereby. Samples sent to London, after being so treated, were valued at 25 per cent. more than the same indigo which had not undergone a similar treatment. This, with the reduction of freight, ought, I think, to induce farther trials of this regenerating or brightening process. When indigo is dried hastily in the sun, it is very apt to become friable or brittle, which disadvantage may be in some degree avoided by slow drying in a shade.

From an account published in France in 1770, St. Domingo alone exported 2,000,000 of pounds of indigo, which paid the export duty; and the extent of country on the Coromandel coast, where the *nerium* grows, is greater than the whole of that island: and it undoubtedly grows in still greater abundance on the Malabar coast, which is more mountainous, and of course more favourable to the growth of the plant: and I have lately been informed that Dr. Scott of Bombay, discovered it growing in the island of Sasset. The common indigo plant can only be brought to perfection in a good soil, and by expensive laborious culture; and it is even then liable to many accidents from changes of weather, and other causes, which no human foresight can prevent. I have not been able to find that this species of indigo is subject to any disease; nor
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have I ever once observed a leaf eaten by any insect or other animal, except by goats and buffaloes, who only eat it from necessity.

In the *second* part of Dr. Roxburgh's communication, he gives a brief account of the results of various experiments made for the purpose of "throwing some additional light on the theory of this artificial production (indigo);" and he professes to have confined himself to such experiments as cannot be well made in Europe; none of the indigo plants employed by him growing spontaneously there. It will be perceived, that Dr. Roxburgh, in describing and reasoning upon his experiments, adheres to the language and principles of that system of chemistry which is now almost exploded by the later discoveries and doctrines of Lavoisier, Cavendish, Berthollet, &c.; and in this respect I have not thought it proper to make any alteration; especially as those who are acquainted with the new system will find no difficulty in understanding and explaining the several phenomena, according to its principles and terms. It will also be perceived that I have generally adhered to the doctor's practice of describing and reasoning on his experiments in the first person singular; but it must not from thence be supposed that I have always copied his own words; for besides the omission of parts which appeared to me of less importance, I have frequently changed his modes of expression for the sake of perspicuity and brevity.

"I have seen," says Dr. Roxburgh, "a short paper by Mr. Robert Blake of Calcutta, who appears to think that the colouring principle of indigo is held in solution by the aerial acid;
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“an opinion which accords with my experiments:” He (Mr. Blake) was induced to make some, which led to this conclusion by the opinion of Mr. Taylor of Manchester, namely, that in the production of indigo, fixed air was absorbed from the atmosphere during the agitation. Mr. Taylor, in his Report to the Lords of the Committee of Privy Council for Trade, &c. observes, that “the use of the violent agitation in the second process has never been clearly ascertained in any account he has seen respecting indigo.” “Its theory (says he) certainly depends on the great attraction which indigo in that state of solution has for *fixed air*; by agitation and exposure to the atmosphere, it absorbs it from common air, and unites with it, and is thereby precipitated. The success therefore of this part of the business may be increased by such improvements in mechanics, as will expose the liquor with the largest possible surface to the atmosphere, (that the affinity may sooner take place,) and by procuring a great circulation of common air in and about the reservoir.” So far Mr. Taylor agrees with me, that we both recommend the exposure of a large surface of the coloured liquor to the atmosphere, and a free circulation of air, which indeed is the main object in view.

When the common indigo plant is committed to cold water in the steeping vat, the following appearances take place: in a few hours, more or less according to circumstances, a slight motion begins to shew itself through the vat or body of liquor; the bulk increases considerably with some additional heat; air bubbles are generated, some

some of which remain on the surface, and gradually collect into patches of froth; a thin violet, or copper coloured pellicle or cream makes its appearance between the patches of froth, and soon after, the thin film which forms the covering of the bubbles composing the froth, begins to be deeply tinged with a fine blue: The liquor from the beginning will have been acquiring a green colour, and now it will appear, when viewed falling from one vessel into another, of a bright yellowish green, and will readily pass the closest filter, until the action of the air makes it turbid, a proof that the (base of the) colour is now perfectly dissolved in the watry menstruum. This is the time for letting off the vat; if suffered to remain, the bulk begins to diminish, and will return to its original dimensions; the fermentation however continues; there is still much intestine motion through the vat; large quantities of froth are formed; hitherto the peculiar smell of the plant will have prevailed, but now it becomes very offensive, somewhat resembling animal matter beginning to putrefy; as the fermentation goes on, the smell becomes more and more offensive, and the quantity of air discharged is less and less, till an absorption takes place." When in the early part of the process I held a glass tube to the mouth of a sixty gallon cask, which served as a fermenting or steeping vat, that I might collect the airs, if any had been discharged, I found the wet bladder which had been tied over the upper end of the tube "strongly pressed in by the external air, a sure proof that the vat in this state absorbed air; but as soon as the bulk of the mass begins to be

be enlarged, a disengagement of airs takes place, and these are the fixed, pure, and impure: about the time when the bulk of the vat or liquor has attained its greatest increase, the fixed air is discharged in greater purity and in larger quantity than at any more early period; and it even continues to predominate until the 9th day, which I call the last stage. When the fermentation had advanced beyond the stage at which the vat ought to be drawn off, I found that a little agitation was necessary to promote a discharge of airs sufficient to fill a bladder." I could detect no volatile alkali in any part of the process: "During the agitating process, fixed air continues to be discharged, and in immense quantities, mixed with pure and impure airs; but still nothing like volatile alkali appears." As soon as the grain shews itself distinctly, the precipitant (alkaline or calcareous) is to be added; from that instant, an absorption of air takes place, and after the liquor has settled a little, a candle will burn freely close to its surface, as long as it would have done in the same quantity of atmospheric air; though, before, it had been constantly extinguished at the moment of its entering the mouth of the vessel. With nerium leaves the fermentation never became so perfect as with the common indigo plant; yet the airs discharged from it were the same, though less in quantity. "By scalding either the common indigo plant (*i. e.* young twigs and leaves) or the leaves (only) of nerium in bottles containing four gallons, nearly the same effects were produced, *viz.* first, an absorption of air, then an increase in the bulk of the mass, with a discharge of pure air at first,

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and

and afterwards of pure air mixed with fixed air, though in a proportion smaller than in the fermenting mixtures; here also during the agitation immense quantities of fixed air are discharged till the grain is formed and the precipitant added, when, as in the other case, an absorption takes place. Here also a lighted candle burnt freely near the surface of the liquor, after the precipitant was added, and once I observed distinctly some explosions of inflammable air. But the liquor being agitated, and a candle immediately after let down into the vessel (bottle), it was instantly extinguished upon entering its mouth."

I took some of the green coloured liquor, before it had suffered any agitation, and with it filled the globe of Dr. Nooth's apparatus for impregnating water with fixed air, into which (liquor) I continued throwing that fluid (fixed air) from a mixture of powdered lime-stone, and diluted vitriolic acid for some hours, but no change took place. After standing till next morning, a very few grains of a greenish precipitate were found in the bottom of the vessel, which I impute to the communication which the liquor had had with the open air before it was put into the globe; for when the leaves had been scalded in bottles of water, inverted in a large vessel of water, or in the globe itself, and committed to the same trial, no grain was found; the liquor continuing uniformly of a pale yellowish green, which is the colour it always, in my experiments, acquired when scalded in the above manner. I kept some full bottles of it inverted in water for a month, and no change took place; nor does the liquor in these circumstances

stances ever acquire the copper-coloured film on the surface, but as soon as the air is admitted to it, greenish blue veins are observed to descend from the surface, in various directions, until the whole becomes blue. This phenomenon is constant, but the colour is more or less deep according to circumstances: soon after a precipitation of blue grains takes place, and the copper-coloured pellicle appears on the surface; but no change appears in the colour of the liquor, nor is any grain formed while the external air is perfectly excluded; neither do the leaves acquire that offensive smell which they do when exposed to the action of the air. "I may therefore, I think, safely conclude, *that fixed air is not the agent by which this colouring matter is separated from its menstruum, but rather that by which it is extricated and kept in solution.*"

Nitrous air from iron filings, and diluted nitrous acid, was also, by means of Dr. Nooth's apparatus, thrown into the coloured unagitated liquor for some hours, without producing any change, except that here the violet-coloured film took place; this liquor was afterwards exposed to the open air, and the usual changes then occurred.

Inflammable air from iron filings, and diluted vitriolic acid, deepened the colour of this liquor much, and it was quickly covered with a deep violet-coloured scum; but no decomposition took place till the air had access to the liquor, when it quickly became of a deep *greenish blue*, and let fall a considerable proportion of precipitate, which, on drying, proved to be most

beautiful indigo. Inflammable air from dry sheep's blood burnt in a gun barrel, as recommended by Dr. Priestley, had not the same effect as that from iron filings and vitriolic acid, the change of colour being much less considerable.

Alkaline air, from a heated mixture of three-fourths of quick lime and one-fourth of sal ammoniac, deepened the colour of the liquor fully as much as the first mentioned sort of inflammable air; it gave a deep violet scum and good indigo after exposure to the open air, but nothing like a separation took place before.

I put into bottles portions of the leaves of the nerium, and of the common indigo plant, to which I added rain water, impregnated with a large portion of what I have always found the most powerful precipitants, *viz.* lime water, caustic ley, stale urine, Prussian lixivium, and phlogisticated calcareous lixivium, (of which more hereafter;) the bottles were inverted in a vessel of water, and scalded to the usual degree; the effect was, that they all became only of a much deeper colour than when no precipitant was used; but nothing like a separation of the colour took place till exposed to the action of the air. I also scalded the leaves in an open vessel, and as expeditiously as possible, so as to allow the air but very little time to act on the liquor, and putting this into bottles with portions of the same precipitants, the bottles were immediately inverted in a vessel of water; and having stood sixteen hours, a little green or olive-coloured *fæcula* (precipitate) was found in each,

each, which I conclude must have arisen from some little action which the air had on the liquor while scalding and pouring into the bottles. This precipitate, when separated and exposed to the air, became indigo of rather a bad quality; and the liquor from whence it had separated, being afterwards exposed to the air, became blue from the surface as usual, and soon gave a blue precipitate of tolerably good indigo. These experiments clearly prove, that the most powerful precipitants added to these liquors, cause no decomposition without the help of the open air: and further, that if the air has had access to this liquor, only while scalding, a very small quantity of green or olive-coloured precipitate may be produced, but that this does not acquire a blue colour without the free contact of the air; they also prove that the colouring principle of Prussian blue does not act on this coloured liquor any farther than the alkali which it contains would have done by itself; it is therefore to be presumed, that both the base and the colouring principle of indigo are totally different from those of Prussian blue.

The coloured liquor, impregnated with the first principles of indigo, either by fermentation or by a scalding heat, if it be only exposed to the open air, and especially with a large surface, will in a short time spontaneously begin to part with its colour, which will fall to the bottom in minute grains of fine blue indigo. Agitation will much hasten the separation and precipitation, and because the produce to be greater; heat will have nearly the same effect, though in less a degree, except when it is joined with agitation, in which case

both agents will act more powerfully than either alone.

The indigo by all these means will prove good if the process has been properly conducted; precipitants are not therefore absolutely necessary to the production of indigo; but if well chosen, and in a due proportion, they will forward the operation much, and cause a larger precipitation than could be otherwise obtained without any injury to the quality, as I have reason to believe from a variety of experiments.

As far as my information goes, these precipitants are universally calcareous, alkaline, or astringent vegetable matters, of which lime-water is the most common, and I believe it is also the best, particularly with nerium; alkalis answer best when they are rendered caustic or deprived of fixed air; but even then the indigo obtained by lime-water will be found purer, though probably not in so great a quantity. It has already been observed, that fixed air forms a very considerable, I may say, the largest portion of the airs discharged during the fermentation, or scalding and agitation; and this being a fluid for which lime has the *greatest attraction*, we may I think conceive the reason of its superiority as a precipitant; for I am convinced that the colouring base of the indigo is held in solution by this acid, and that the more it is deprived of it before the precipitant is added, the more perfect will the granulation prove; and that a much smaller portion of lime-water (as a precipitant) will then answer perfectly well.

Next

Next to lime-water may be reckoned caustic ley, made from vegetable alkali and quicklime; this generally gives more of the precipitate, but its quality I have always found to be inferior to that by lime-water under similar circumstances. I have also observed, that this ley, when perfectly caustic, throws down some of the other extractive matters of the plant along with or before the blue. If the ley be added before the liquor has been agitated, or any granulation taken place, these extractive matters will generally be precipitated first in the form of a dirty pale yellow *fæcula*: and in the mean time, the supernatant liquor gradually acquiring from the surface a deep blue colour, will soon become turbid, and then a blue precipitate of real indigo will at length take place over the first; this proves the impropriety of using a caustic ley, where indigo of the best quality is desired, as it ought to be by every manufacturer. This caustic ley changes the unagitated green liquor into one of a brownish colour, which quickly becomes blue; and these changes proceed so suddenly as to escape notice without particular attention. When the ley is made less caustic, *i. e.* by using a *lixivium* of wood-ashes and lime-water mixed, it gives a better coloured precipitate, and perhaps one nearly as good as that of lime-water.

Stale urine is also a powerful agent: the colour of the indigo precipitated by it is always very bright, but considerably lighter than that with lime-water or caustic-ley.

When a green or olive supernatant liquor follows the use of lime-water or caustic-ley, (which is but too common in making indigo by fermentation, to the great loss of the manufacturer,) I conceive it to be owing to the presence of fixed air, still adhering to, and keeping dissolved a portion of the base; this fluid not having been sufficiently extricated by the fermentation or scalding; or by the extent of surface, agitation and action of the agent employed*.

From this dark green or olive supernatant liquor, a farther precipitation may be obtained by the same means which produced the first, and it will be found when dried of as dark or darker a colour, but considerably duller.

In the northern parts of the coast of Coromandel, the natives use a cold infusion of the bark of *jambolifera pedunculata* of Linnæus, (jambolong tree,) which is a very powerful astringent, to precipitate their indigo, which they always extract from the leaves by *hot* water; they have no idea that indigo can be made with cold; nor is it necessary to teach them on this point, what they make being of a very good quality. I have tried many other vegetable astringents, but without any good effect; the principles on which this one acts, I cannot determine.

* This opinion of Dr. Roxburgh's does not seem well founded; there is much more reason to conclude, that from some cause or other, the vegetable basis of the indigo in this case, has not attracted and united to itself a sufficient portion of oxygene, on which its blue colour most certainly depends.

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The *mild* vegetable, mineral, and volatile alkalis act also as precipitants*, but less advantageously than those already mentioned. Mineral acids added to the coloured liquor in small proportions, either before or after the agitation, do not hinder the precipitation, though I cannot say they forward it †.

The solutions of iron, lead, tin, mercury, and copper, either injure or entirely destroy the colour ‡.

I have tried many other substances and mixtures, as well for the purpose of precipitating the colouring matter as of washing it when precipitated, but without finding any so useful as

* If it were true, as Dr. Roxburgh supposes, that the precipitants of indigo act only by absorbing or separating the fixed air, which he conceives to be still remaining in the liquor united to the unprecipitated particles of indigo, it would be difficult to conceive how the mild alkalis, saturated as they are by fixed air or carbonic acid, should occasion any, even the smallest degree of, precipitation.

† One of the mineral acids possesses the power of dissolving indigo without changing its colour; another totally destroys the colour; and the third appears to have no action whatever, either on the colour or the texture of this substance. If therefore such very dissimilar agents agree in not acting so as to hinder the precipitation of indigo, it must be only because they are employed in proportions too small to admit of their having any perceptible action; and in this way any thing may be rendered inactive.

‡ The facts stated in chapter fifth of this volume prove, that several of these metals act very powerfully, and in very opposite ways, either in promoting the solution of indigo, or in rendering it absolutely insoluble: it therefore seems inaccurate at least to apply the same observation to substances of such dissimilar action, and capable of being still farther varied by the various solvents here left undetermined.

lime

lime for the first, and pure vitriolic and muriatic acids for the second of these purposes.

Alum I have found to be a most powerful agent; but it debases the quality of the indigo. With the liquor of nerium leaves which had been scalded until they were beginning to boil, it produced a large quantity of green precipitate which retained its colour after being dried*.

Dr. Roxburgh concludes, that neither the nerium nor the common indigo plant yield any thing more than the base or basis of colour, which he conceives to be naturally green, and to continue so, as long as it remains dissolved in the aqueous menstruum employed to extract it from the leaves; which, by being deprived of this basis, become of a dirty yellow colour. He concludes also, that the fixed air, or carbonic acid gas, extricated so abundantly during the extraction of this basis from the leaves, is yielded by them, and is the agent or medium by which the basis is kept dissolved; and that water, naturally impregnated with this acid and calcareous matter, is better fitted to extract a pure colour from nerium leaves, than it is when not so impregnated.

To precipitate indigo in the best form, and of the purest quality, (says Dr. Roxburgh,) means are to be used which weaken or destroy that at-

* Here by taking the basis of indigo before it had become blue by an absorption of oxygene, and uniting it as an adjective colour to alumine, it seems to have lost its particular affinity for the basis of pure air, and been disposed to remain always green.

traction

traction which fixed air has for this vegetable base. These means are exposure to the open air, and agitation, together with quicklime and caustic alkalis (which have the greatest attraction for fixed air). By these, the vegetable base being disengaged from the fixed air, unites more perfectly with its colouring principle, which it greedily absorbs from the atmosphere, (assisted probably by the action of light,) forming therewith a coloured insoluble fæcula, which soon falls to the bottom. This precipitate washed and dried is then indigo. "I cannot with any degree of certainty say, what this colouring principle is, but I conjecture it is that of *inflammability*."

I have already observed, that the Hindoos throughout the northern provinces or circars make all their indigo by means of hot water, (which I call the scalding or digesting process,) and precipitate with a cold infusion of the bark of the jambalong tree, which is a very powerful astringent: yet notwithstanding the inferiority of this their agent, (which habit has rendered sacred,) when its effects are compared with those of lime-water, I have always found their indigo, if it be not intentionally adulterated, to be of a very excellent quality, and *very light*; a cubic inch weighing only about 110 grains, and being of a blue violet colour. The superior quality of this indigo must alone be imputed to the nature of the process by which the colour, or rather base of the colour, is extracted from the plant; for their apparatus is very inconvenient. They use only common earthen pots, holding about four or five gallons each; in which the fresh
tops

tops and leaves of the common indigo plant are scalded, rather more than is necessary for extracting the colour from perium leaves: they pay little attention to the nature of water, provided it be clear: their agitation-vat is nothing but a large jar; and the rest of the process is so carelessly conducted, that the excellence of their indigo seems only to result from and be a proof of the superiority of the scalding over the fermenting process.

In many parts of the Carnatic, they also extract the colour by hot water, but debase the indigo by adding a mixture of red earth and water, which they employ as a precipitant.

Besides the superior *quality* of the indigo obtained by the scalding process, the quantity is generally increased by it; for in this way the whole of the colour is always extracted at first, if the scalding has been continued long enough; which is not the case by fermentation, as the leaves will yield indigo upon being fermented a second time. (See the Translation of M. de Cossigny's Treatise on Indigo.) Moreover the health of the labourer in this way is not endangered, as in the fermenting process, by constant and copious exhalations of putrid miasma: the heat employed expels most of the fixed air during the scalding, which renders a very small degree of agitation, and very little of the precipitant necessary. The operation can also be performed two or three times a-day upon a large scale; and lastly, the indigo itself dries quickly without acquiring any bad smell, or putrid unwholesome tendency.

According

According to M. de Cossigny, the Javanese first ferment the indigo plant, then boil the coloured liquor a little before it is agitated, and do not seem to use any other agent to assist the granulation and precipitation. The indigo itself he describes as being very fine, and much esteemed in Europe, which I attribute to the boiling, or as I should imagine scalding of the liquor.

To the second part, Dr. Roxburgh subjoins an Appendix, containing a botanical description and drawing of a second *new* indigo plant; a species of *indigofera*, which, says he, I conceive to be a new one; and which on account of the property of its leaves, I have named *indigofera cœrulea*. It is called by the Hindoos of these parts *car-necli*; and is an erect shrubby species, growing naturally on dry, barren, uncultivated ground to the height of from one to three feet, and more in good garden soil. It nearly resembles the *indigofera argentea* Lin. the chief difference being that the new plant is wholly destitute of down, and the leaves are never three'd, but always composed of from three to five pairs of leaflets, with a large single terminal one, and the legumes are very numerous on the same racemus.

From the leaves of the plant I have often extracted a most beautiful light indigo, more so than I ever could from the common indigo plant, or even from those of the *nerium tinctorium*, and in a large proportion. After an inquiry of two years, I have not been able to discover, that the natives of any part of India
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make any use of this plant. The process, by which I obtained the colour from the leaves, was the same as that which had produced it from those of the nerium, *i. e.* by committing them to cold water, and heating it over a moderate fire to about 160 degrees of Fahrenheit's thermometer, when the liquor will acquire a *beautiful deep greenish yellow colour*. It is then to be strained off clear, and while hot, gently agitated in a broad, shallow, open vessel for a few minutes, during which time it changes its colour, gradually becoming darker and more turbid; when sufficiently agitated, if a little of it be viewed in a clean silver spoon, or other vessel reflecting the light, a muddiness or minute grain may be seen, which will be rendered large and copious by the addition of a little lime-water, and soon after precipitated to the bottom: after which, the super-incumbent liquor being poured off, it will incline more or less to a clear brandy colour, according as the operation has been more or less successfully conducted; for the more this liquor is tinged with green, the less perfectly will the colour have been separated, and the produce will of course be less copious and beautiful. How to effect the most perfect separation and precipitation of the colour, is the great *desideratum* with our indigo manufacturers, and well deserves the chymist's most serious attention.

On the 1st of September 1792, says Dr. Roxburgh, I scalded eight pounds of the leaves of the *Indigofera coerulea* in hard water, and six pounds and a half in soft water; they required more scalding than those of nerium, or even of

the indigofera tinctoria, and more agitation to produce a granulation, particularly that with rain water, which has always, even with the other plants, seemed to act less effectually as a menstruum than hard water. The *fecula* was precipitated by one part of lime-water to 75 of the coloured liquor, and being washed with diluted vitriolic acid, and afterwards with scalding water, when dry, afforded the most beautiful indigo I ever saw; that with hard water was the best, but the proportion of indigo was in both nearly the same, *i. e.* eight pounds of leaves with hard water, gave 241 grains; and six pounds and a half with rain water, gave 199 grains.

To the facts and explanations thus communicated by Roxburgh, I shall add but a few observations. His account of the appearances and changes which arise during the fermentation of the indigo plant, seems to be much more accurate than any yet offered to the public; many of them are however such as attend the fermentation of other vegetable matters, and not essentially connected with the production of indigo; as its generation or production by the *scalding* process, undeniably proves. For a knowledge of this process, we are indeed more especially indebted to Dr. Roxburgh; and the process itself seems highly interesting, because it doubtless must prove in many respects greatly preferable to the other; and because it presents to us a more simple view of the changes and effects which are essentially necessary to the production of indigo, divested of those which are common to other fermenting vegetables. The
appear-

appearances and successive alterations through which the green liquor obtained by scalding the indigo plant, becomes finally blue upon the access of air containing oxygene, and afterwards deposits that singular fæculence under consideration; joined to the absolute impossibility of producing these effects, by any of the other airs and mixtures which Dr. Roxburgh very judiciously applied for that purpose, to the green liquor, *so long as it was kept secluded from oxygene, all serve to confirm* what I have advanced in the fifth chapter of this volume, and to prove that the blue colour, and the peculiar properties of indigo result wholly from a combination of oxygene with its vegetable basis; and I am confident that Dr. Roxburgh, upon re-considering the subject, will accede to this conclusion.

I have no doubt of the possibility of obtaining the very best indigo from that which is of a very ordinary quality; the faults of indigo generally arise not so much from a want of the true colouring matter which belongs to it, as from an admixture of other heterogenous and useless matters by which it is debased; and from some trials which I have made, there is reason to believe, that these may all be dissolved and separated by powdering the indigo, and subjecting it first to the action of a lixivium of pot-ash made caustic by lime, and afterwards, of the muriatic acid diluted by a sufficient proportion of water; taking care first to rinse and carry off by warm water whatever the alkali may have dissolved; there is hardly any extraneous matter which one or other of these agents will not

not dissolve, though neither has any action upon indigo itself. I prefer the muriatic to the sulphuric acid for this purpose, because it will prove at least equally efficacious for dissolving all, and more efficacious than the sulphuric acid for dissolving many of the heterogeneous matters in question, particularly the oxyds of iron, and of other metals, without a possibility of its having any action upon the pure colouring matter of the indigo, which may not be true of the sulphuric acid: for though the latter, when very much diluted, seems to have no power of dissolving indigo; yet, I think, if it be used of a sufficient degree of strength to act efficaciously on the other adhering matters, there will be danger of its likewise carrying off some of the true colouring matter of the indigo, and thus occasioning a diminution or loss of that precious substance. It may however be doubted, whether any considerable benefit would result from this method of purifying indigo, (the saving of freight alone excepted,) since it could not add to the portion of colouring matter which the indigo previously possessed; and dyers now generally know how to estimate, and derive the utmost advantage from, that portion which even the worst indigo contains. It is said, indeed, that the sulphuric acid brightens the colour of the indigo to which it has been applied in this way; an effect which I can readily believe, from its analogy to what happens from the application of it in making the preparation used for Saxon blue. This, however, must be a fallacious brightness, which can add nothing to the useful properties of indigo for any purpose, and may prove disadvantageous for all

those in which it is to be employed with an alkali; because more of the latter will in that case be necessary to overcome the excess of oxygene, which the indigo will have acquired from the sulphuric acid, and which will have produced the fallacious brightness of its colour.

In the year 1793, one of the most eminent mercantile houses in London received from Bengal, parcels of two new drugs intended for dying; samples of which were soon after put into my hands, with a request that I would make suitable trials of their merits; and with a paper containing some explanations which had accompanied them from India. One of these (and the only one which I shall notice at this time) was called by a name composed of foreign words, signifying *green* indigo. It was formed into dry hard cakes, resembling in size and shape those of the indigo sent from Bengal; but of a dark dull green colour. It was stated to be a simple substance, and to have been prepared with water and fire only, from an *indigoferous* plant, of which a description was indeed given; but I am in doubt, whether by publishing it I should not go beyond the intentions of the author of this discovery: it was also represented as giving a durable light green colour, without any mordant or basis, to silk and wool; and to be incapable of dying dark green without the aid or addition of some blue colouring matter. To bring this green indigo into a state fit for use, it was directed to be finely levigated with sand, and then boiling hot water was to be poured upon the powder in a suitable vessel; and being left to settle, the water “tinged
7 with

with a dirty brown colour was to be poured off;" and these washings were to be repeated until the water came from the powder colourless; and then to the remaining powder, an equal quantity of fixed vegetable alkali, obtained by calcining salt-petre upon burning charcoal, was directed to be added, with a proportionate quantity of water, and the mixture made to boil for two or three hours; after which, it was to be left "to digest for two days at least." In this preparation, diluted with boiling water, the silk or woollen stuff was directed to be dipped for the space of half an hour; and then washed with soap in water; a longer dipping was represented as giving no greater body or depth of colour.

Those who may recollect what I have mentioned respecting a supposed new green indigo, at page 144 of this volume, will naturally conclude, that my curiosity must have been greatly excited by that now under consideration; and indeed I lost not a single minute in making a trial with it, which I knew capable of decisively ascertaining, whether it really possessed the properties of indigo, the difference of a green instead of a blue colour only excepted. This was by powdering and boiling it in water with a suitable portion of lime, pot-ash, and red orpiment, as is practised in making the printers blue for penciling (see page 113, &c.); and in doing this, I soon perceived, with great satisfaction, that the mixture exhibited exactly the same smell, and the same appearances, as those which arise in making the printers blue; the surface of the liquor was covered with a fine

shining copper-coloured scum, and beneath this, when separated, the liquor itself exhibited a lively green. Being impatient to see how far its effects were similar to those of indigo dissolved in this way, I applied some of the green liquor as expeditiously as possible, by the pencil, to a bit of callico, and soon perceived that it consisted of two very dissimilar colouring matters; one, which proved to be true indigo, was immediately revived by an absorption of oxygen, (as happens to the printers blue when so applied,) whilst another part of the liquor spread itself farther, and retained a kind of olive green colour, which the air did not change,

The callico after being dried was washed with soap, and that part of the liquor which had spread farthest, and retained the olive green colour, was soon wholly washed out, leaving behind the pure indigo adhering to the spots and strokes where it had been applied. Having thus convinced myself that this substance contained a portion of true indigo, I powdered an ounce of it, and mixed the powder with six times its weight of sulphuric acid, as in making the sulphate of indigo for Saxon blue: in about twenty-four hours the powder appeared to be nearly all dissolved, and the solution was of a blue colour with a greenish tinge: and by putting a little of it into warm water, and dying a small piece of flannel therein, a full Saxon blue was soon produced; though the colour had a greenish cast, occasioned manifestly by the same olive-coloured matter which I have just mentioned as having shewed itself upon the callico.

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I afterwards tried the method recommended by the author of this discovery, of separating the yellowish brown colouring matter from the powdered green indigo, by repeated ablutions with hot water, and then employing a pure caustic vegetable alkali to dissolve the residuum. In this way I obtained a solution which, upon wool, dyed a light olive or apple green; I found however, as I had foreseen, that none of the true indigo had been dissolved either by my trials or those made in Bengal, it being impossible, as I have formerly explained, to dissolve indigo by caustic alkali alone; and indeed the discoverer of this preparation, in the account which he transmitted from Bengal, candidly acknowledges that he had never been able to dissolve the supposed green indigo "entirely, a considerable quantity having always remained precipitated at the bottom of the vessel." And this insoluble residuum (which appears to have been lost, or at best to have remained wholly useless in all the experiments made in Bengal) I found by further trials to be true indigo. For by separating the solution made by caustic vegetable alkali from the residuum, then pouring upon the latter farther portions of caustic alkali in hot water, until the lixivium came away colourless; and afterwards submitting what remained to the action of muriatic acid, to dissolve any heterogeneous matters which the alkaline menstruum had left behind, I at length obtained a considerable quantity of indigo of a middling quality; part of which, being dissolved by sulphuric acid, dyed wool of a good Saxon blue colour, without any of the greenish tinge which had attended my first trials; and another part being dissolved by
pot-ash,

pot-ash, lime, and red orpiment, as for the printers topical blue, produced the usual effects of indigo in this way. Having applied the acetite of alumine topically to a piece of cotton, as is practised in callico-printing, and dyed one part of it in the yellowish brown coloured liquor, which had been obtained by pouring hot water on the supposed green indigo in powder, and another part in the olive green liquor, obtained from the same powder by caustic vegetable alkali, I found that, though each imbibed a different colour; neither was fixed upon the figures which had been printed with the aluminous basis, or on the parts to which no mordant or basis had been applied, and that the colours were removed by washing with equal facility from every part: a certain proof that the yellowish brown and olive green colouring matters were not of the adjective kind, (having no affinity with the aluminous basis,) and that they are not likely to be of any use in dying; for though they should prove lasting upon woollens, there are many other and much cheaper means already in use, for giving colours of this kind to wool. It seems evident, therefore, that the true nature of the supposed green indigo was but very little known to the discoverer thereof; and that its useless heterogeneous parts were the only ones which produced the colours dyed in Bengal, and which induced him to send it to Europe as a dying drug.

Whether the supposed green indigo owes its production to an insufficient combination of oxygene; or, in other words, whether the matters which dyed the yellowish brown, and the olive

olive green colours, before mentioned, are similar to that which forms the basis of true indigo, and capable of being converted thereto by a longer fermentation, agitation, &c. ; or whether they are of a nature essentially different from the basis of indigo, though naturally combined with it in the particular plant from whence the substance under consideration is extracted, are important questions which I am unable to answer. I have indeed mixed the supposed green indigo, in powder, with water, and kept the mixture for several days at a degree of warmth suited to promote a fermentation, but without being able in this way to render its colour blue, or increase the proportion of true indigo which it had before contained: but perhaps I might have been more successful with a greater quantity, or a larger fermentible mass, than what I was able to employ in this way.

I have had reason to conclude that the supposed green indigo, either from a redundancy of colouring matters in the plant from which it was extracted, or from some other cause, may be obtained at much less expence than the true indigo; and if this be the case, it must doubtless prove a very important discovery, in case the yellowish brown and olive green matters are capable of being changed to indigo, by a farther combination of oxygene: and even if this should not be the case, perhaps the plant may deserve attention, on account of the portion of true indigo which it unquestionably affords; and which, by an alteration in the process, might doubtless be precipitated and collected free from the other matters before mentioned, which, in
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their present state, must prove hurtful instead of being useful, as the author of this discovery had expected.

At page 145 I have said, that no substantive vegetable yellow had, as I believed, ever been employed in Europe; I have however learned, since that part of the present volume was printed, that among other means for imitating the silk handkerchiefs brought from India and China, a tincture of turmeric is applied *specifically*; and that it produces a *substantive* yellow, which on silk proves sufficiently durable, and indeed much more so than I could have believed from the trials which I had before made with it in other ways. I have been shewn and have repeated the whole process by which this imitation is very ingeniously performed; but it might be considered as a breach of confidence were I to publish any more on this subject.



END OF THE FIRST VOLUME.